THE INFLUENCE OF INANITION ON METABOLISM

BY

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WASHINGTON, D. C.

Published by the Carnegie Institution of Washington

1907

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CARNEGIE INSTITUTION OF WASHINGTON

PUBLICATION NO. 77.

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

PREFACE.

The primary object of this report is to present an accurate statement of the results of experiments on the effect of inanition on metabolism made with a number of men in the chemical laboratory of Wesleyan University, Middletown, Connecticut. It is believed that physiology and physiological chemistry will be best served by presenting the data accurately and in sufficient detail rather than to sacrifice the protocols for a discussion that at best can be but inadequate. The accumulation of the experimental data, the computation of the results, and the preparation of this report have been made possible only by the fidelity and loyalty of my associates.

Mr. T. M. Carpenter, in immediate supervision of the greater number of the respiration calorimeter experiments, has conducted these most wearisome experiments with unusual success.

Mr. H. A. Pratt, aside from rendering valuable assistance in the chemical laboratory, has superintended the computations and tabulations, and the entire report has received his helpful editorial criticism.

Mr. E. M. Swett acted as physical and chemical assistant and superintended the determinations of the heats of combustion with the bomb calorimeter.

Miss Charlotte R. Manning had charge of all the gas analyses, carbon and hydrogen combustions, creatinine determinations, and the analyses of food.

Mr. E. R. Fulton made all the determinations of sulphur and phosphorus.

Mr. F. P. Fletcher acted as physical assistant in the later series of calorimeter experiments.

Messrs. J. A. Riche and R. R. Hartman assisted in the chemical and physical measurements.

Mr. W. H. Leslie, Miss A. N. Darling, and Mr. H. C. Morgan have had a large share in the tabulation of the results of the experiments and in the final preparation of the report.

The stenographic work was in charge of Miss A. N. Darling, who was ably assisted by Miss M. K. Falsey.

Aside from a corps of students, special mention should be made of the assistance in the computations rendered by Messrs. H. L. Knight and F. W. Harder and Misses H. W. Atwater, E. J. Wright, and H. L. Alling.

It is a great pleasure to express my deep sense of obligation to all of these co-workers in the conduct and presentation of the results of experiments that call forth all the patience and accuracy of the trained chemist, physicist, and computer.

My thanks are especially due to Dr. A. R. Diefendorf, pathologist of the Connecticut Hospital for the Insane, Middletown, Connecticut, and Prof. Lafayette B. Mendel, of Yale University, New Haven, Connecticut. I have from time to time enjoyed the valuable counsel and advice of both these gentlemen. Dr. Diefendorf personally made a very large number of the blood examinations and furnished a statement which has been embodied in this report. Professor Mendel suggested the desirability of determining the creatinine in the samples of urine in the fasting experiments. Some of the determinations he kindly made in the New Haven laboratory. In this work he was assisted by Mr. O. E. Closson.

F. G. B.

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Middletown, Connecticut, December 21, 1906.

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Food is usually ingested at more or less regular periods, so that the anabolic processes proceed without interruption; but, by withholding food, the anabolic activities may be depressed to such an extent as to make the study essentially one of katabolism. Consequently, studies of the transformations in the body during inanition are of great value and, logically, at least, should precede the studies in which anabolic and katabolic processes are combined.

While it may legitimately be considered that the first day without food is not a true fast, i. e., a metabolism in which body material alone is involved, because of the presence of unabsorbed or partially digested food in the alimentary tract, it nevertheless seems highly probable that by the time the second day of fasting begins the body is living essentially upon its own substance. Since, however, the retention of fecal matter may result in a more or less prolonged absorption and thus vitiate in a small way the assumption that only preformed body material is being consumed, experiments of more than two days' duration are necessary, and consequently experiments during prolonged fast should be included in any complete and accurate study of metabolism during inanition.

Although as a rule man is disinclined to fast more than half a day, many persons have lived with no food whatever for periods as long as 30 or 40 days. It is important here to distinguish between complete abstinence from both food and water and abstinence from food alone. Experiments have shown that life can not be sustained for any considerable period when both food and drink are withheld. It was the popular impression, at least in the early and middle ages, that certain persons were able to subsist upon body material alone for much longer periods of time, extending, indeed, into years. Fasts of more than one day's duration may be divided into six classes.

RELIGIOUS FASTING.

Fasting as a religious rite has in many recorded instances been prolonged, and more or less complete. The accounts of such fasts are, however, so clouded by superstition and show such a lack of accurate observation that they are without value to science. They served only to maintain popular belief in the ability of some religious ascetics to subsist solely on the eucharist, and of some possessed of devils to abstain from food altogether. Of the numerous recorded instances of this form of complete or partial inanition, many are cited by Hammond[a] and Luciani.[b]

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[a] Fasting girls; their physiology and pathology. New York, 1879. In this little volume Hammond refers to cases cited by Görres (La Mystique divine naturelle et diabolique, Paris (1861), 1, p. 194); and Wanley (Wonders of the little world, London, 1806, p. 375).

[b] Das Hungern, Leipzig, 1890, p. 70.

Aside from those directly connected with the church and religious orders, numerous instances of prolonged fasting, in general by young girls, are recorded.[4]

However interesting these and the many similar instances may be to the psychologist and theologian, they can of necessity have no scientific value, and any attempt to discuss them and the degree of probability of the various conditions asserted as controlling them would be out of place here. Our present-day knowledge of the processes of metabolism is fixed to such a degree that fasts as prolonged as many of the religious fasts were asserted to have been are inconceivable. It remains, however, to be proven that there may not be instances of suspended animation approximating the hibernation of the cold-blooded animals, in which man may subsist on his own body substance for a period of months. On this point, however, scientific observations are lacking.

FASTING OF THE INSANE.

A characteristic of many delusions is a revulsion towards food and drink, so marked indeed that in many instances all the skill of the trained psychiatrist is required to combat it. In a large proportion of such cases, artificial feeding must be resorted to.

In a number of instances such insane patients have been allowed to fast for a number of days and observations of more or less value have been made upon their general condition of nutrition. In many other instances the fasting had proceeded for a considerable time before the condition of the patient became known to the physician. Hammond[5] cites the case recorded by Esquirol[6] of a person suffering with melancholia who died after 18 days of complete abstinence; Desportes,[7] of a similar patient who lived for two months, consuming only a little water.

Francis[8] reports a case of a supposedly bewitched negress who took but two small cups of water during 3 weeks. McNaughton[9] reports a case of a young man who lived with no food, but with water, for 53 days.

Other cases are cited by Luciani,[10] and it is unmistakably true that fasts of weeks, if, indeed, not months, have been observed in cases of insanity. Modern

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[4] Hammond refers specifically to the work of Bucoldianus, "De puella quae sine cibo et potu vitam transigit," Parisiis Ann., MDXLII; Citesius, Opuscula Medica, Parisiis, 1639, p. 64; Fabricius, Observationum et curationum chirurgicae, centuria secunda, Genevae, 1611, p. 116; Fowler, A complete history of the Welsh fasting girl (Sarah Jacob), with comments thereon, and observations on death from starvation, London, 1871.

[5] Loc. cit., p. 64.

[6] Des maladiès mentales, Paris, 1838, p. 203.

[7] Du refus de manger chez les aliénés, Thèse de Paris, 1864.

[8] New York Medical and Surgical Journal, vol. II, p. 31, cited by Hammond.

[9] Copeland's Dictionary of Medicine, vol. I, p. 31, cited by Hammond.

[10] Loc. cit., p. 218.

methods of treatment preclude such prolonged fasts, since as a rule nutritive enemata and tube-feeding are regularly employed.

STARVATION THROUGH ACCIDENT.

There are on record many authentic cases of persons in shipwrecks, coal-mine disasters, etc., who have been deprived of food for considerable periods. In a number of these cases [11] individuals have been rescued after having withstood fasts of from 14 to 25 days, though in nearly every instance drinking-water, at least in limited amounts, was accessible.

PATHOLOGICAL FASTING.

Pathological cases involving disturbances of the alimentary tract which preclude the ingestion of food are unfortunately only too common, and since the majority of such cases have been in the hands of intelligent physicians, careful observations have been recorded in many instances. Since the method of treatment involved the ingestion either per os or per rectum of varying quantities of food, such cases are not comparable with complete fasting. Furthermore, the pathological nature of the cases may in many instances have resulted in an abnormal metabolism.

FASTING IN HYPNOTIC SLEEP.

To this class undoubtedly belong many of the so-called cases of suspended animation which have frequently been observed in the Hindu fakirs, and more especially in recent years in certain cases in which hypnotic suggestion has been of practical use in studying problems of nutrition. The best known instance of the use of hypnosis for this purpose is the case reported by Hoover and Sollman.[12]

PHYSIOLOGICAL FASTING.

Physiological fasting as distinguished from fasting as a result of mental or pathological lesions may be defined as the voluntary fasting of normal subjects. Either for purposes of exhibition or scientific experiment, a number of such fasts more or less prolonged have been made.

Giovanni Succi, the professional faster, has made a number of fasts of from 10 to 30 days' duration. During many of these fasts scientists have cooperated to secure more or less complete physiological studies of the effect of fasting on metabolism.

Other professional fasters—Cetti, Breithaupt, and Jacques—have been the subjects of experiments which have contributed greatly to our knowledge of the physiology of fasting. One of the most elaborate of such studies is that

[11] Luciani, loc. cit., p. 73; Hammond, loc. cit., p. 62.
[12] Journ. of Experimental Medicine (1897), 2, p. 403.

of a 5-day fast made with a medical student, "J. A.," in the Stockholm laboratory by Johansson, Landergren, Sondén, and Tigerstedt. These and other experiments with men will frequently be referred to in this report.

An examination of the various kinds of fasts outlined above shows that a distinction may be made between what may be termed normal and pathological fasting. The first, second, and probably even the third class should be included, with the fourth, under the head of "Pathological fasting." A criticism has been raised [13] as to whether insane patients are abnormal as regards their metabolism. According to Tuczek [14] there is every reason to believe that in many instances persons mentally unsound have an abnormal metabolism. Admitting that the mental attitude may produce abnormalities in metabolism, it is not at all unreasonable to suppose that in instances where persons are deprived of food through accident the mental strain may likewise result in abnormal metabolism. It is thus seen that only in the case of the hypnotic subjects, professional fasters, and other voluntary subjects, can we have what may be clearly asserted to be normal or "physiological" fasting.

STUDY OF FASTING WITH ANIMALS.

Recognizing the difficulty of securing willing human subjects, investigations on the metabolism of fasting animals, usually dogs, have been made. The results obtained are of value to physiology in general, but of less value to human physiology. The metabolism of the dog is not that of man, for the nature of the food is such as to demand markedly different treatment in the alimentary tract. Both the stimuli to secretion and the composition of the digestive fluids are markedly different, and it seems probable that the deductions from the experiments with animals are of questionable value when applied to man. This is perhaps even more noticeable in experimenting in pharmacology than in physiology, yet it is true that marked differences in physiological characteristics are observed between animals and men. While, therefore, in this report the attempt is made to give a complete bibliography of scientific experiments on fasting men, reference in the text to experiments on animals is made only as occasion demands, and there is no attempt to present a complete list of the experiments on fasting animals.[15]

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[13] Atwater, Eleventh annual report of the (New York) State commission in lunacy (1899), p. 202; Folin, Amer. Jour. Insanity (1904), 60, No. 4, and 61, No. 2.

[14] Archiv für Psychiatrie u. Nervenkrankheiten (1884), 15, p. 784.

[15] F. A. Falck, Beiträge zur Physiologie, Hygiene, Pharmakologie und Toxikologie (1875), has an excellent bibliography of all work on metabolism during fasting completed prior to 1875. Other bibliographies of the subject are given by Weber, Ergebnisse der Physiologie (1902), 1, p. 702; Schaefer, Textbook of Physiology (1898), vol. I, p. 891; Atwater & Langworthy, A digest of metabolism experiments (1898), Bull. 45, Office of Experiment Stations, U. S. Dept. of Agriculture; in the preparation of this report, the excellent Index Catalogue of the Library of the Surgeon-General's Office, U. S. Army, Washington (1880-1904), has been of great assistance.

STUDY OF FASTING WITH MEN.

While, as was seen in a preceding section, it has not been uncommon for man to fast, efforts to make a scientific study of fasting other than the general observations as to loss in weight, strength, etc., were not made until a comparatively recent date. Autopsies were occasionally made on the bodies of persons who had died as a result of inanition and the results recorded by attending physicians, but the first scientific experiment to determine the effect of fasting on metabolism in man was not made until 1825, when Lassaigne[16] studied the urea output of an insane patient who fasted 18 days.

The first observations on the carbon dioxide elimination of man during inanition were made by Scharling[17] in 1843.

The most extended researches on the metabolism of man during inanition are those made on the professional faster Succi by Luciani,[18] E. Freund and O. Freund,[19] D. Baldi,[20] Ajello and Solaro,[21] Daiber,[21a] Brugsch,[22] and Tauszk.[23] The experiments of Lehman, Müller, Munk, Senator, and Zuntz,[24] on the professional fasters Cetti and Breithaupt, and the observations of Johansson, Sondén, Landergren, and Tigerstedt[25] on a medical student, included deter-

NOTE.—Since this report was written, three papers reporting the results of a 15-day experiment (March 9-24, 1906) with a professional fasting woman (Schenk) have appeared from the second medical clinic in Berlin. These three papers appeared in the Zeitschrift für experimentelle Pathologie und Therapie (1906), vol. 3: Gesammt-N- und Aminosäurennausscheidung im Hunger, Dr. Theodor Brugsch and Dr. Rahel Hirsch, pp. 638-645; Die Säurebildung im Hunger, M. Bönniger and L. Mohr, pp. 675-687; Ueber die Darmfäulniss im Hunger, R. Baumstark and L. Mohr, pp. 687-691.

In a private communication Dr. Otto Folin, of the McLean Hospital at Waverley, Mass., has announced the analyses of the urine in a 6-day fasting experiment with an insane man. Dr. Folin also writes that Dr. E. P. Cathcart, of the University of Glasgow ~~Edinburgh,~~ is at present studying the nitrogenous output of man during inanition. Neither of these investigators has as yet published his results.

With the cooperation of Dr. A. R. Diefendorf, of the Connecticut Hospital for the Insane at Middletown, Connecticut, the writer has recently completed the analyses of the urine of a fasting insane woman who abstained both from food and drink for 110 hours and from food a total of 161 hours. The results are reported in the American Journal of Physiology, 1907, 18.

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[16] Jour. d. chim. med. (1825), I, p. 272, cited by Voit (Herman's Handbuch der Physiologie (1881), VI, i, p. 84). Voit also records many other early observations regarding urea output during fasting.
[17] Annalen der Chemie und Pharmacie (1843), 45, p. 244.
[18] Das Hungern, Leipzig, 1890.
[19] Wiener klin. Rundschau (1901), 15, pp. 69-71 and 91-93.
[20] Centralbl. f. klin. Medicin (1889), 10, p. 651.
[21] La Riforma Medica (1893), IX, 2, p. 542.
[21a] Schweiz. Wchschr. Pharm., 34, p. 395.
[22] Ztschr. f. exper. Path. u. Therapie (1905), 1, p. 419.
[23] Orvosi hetilap, Budapest (1894), p. 512.
[24] Archiv f. path. Anatomie u. Physiol. u. f. klin. Medicin (1893), 131, Supplementheft 1-228.
[25] Skan. Archiv f. Physiologie (1897), 7, p. 29.

minations of the respiratory gases. Finally reference should be made to the study of fasting metabolism by Sadovyen[*] in the Pashutin apparatus at St. Petersburg, in which not only the nitrogen but the carbon dioxide elimination was determined, the 1-day experiment of Likhachev[*] in the Pashutin apparatus, which was so modified as to measure the heat elimination, and the observations of van Hoogenhuyze and Verploegh[*] on the fasting girl Flora Tosca.

PLAN AND PURPOSE OF THE EXPERIMENTS HERE REPORTED.

The importance of the study of the fasting metabolism was early recognized in the experiments on the nutrition of man that have been in progress in this laboratory, and the results of three 24-hour experiments and one 48-hour experiment were reported.[*] In these experiments the determinations included those of nitrogen, carbon dioxide, water, and heat. In the computation of the results of these experiments, the assumption was made, as is usual in metabolism experiments in which the determination of the oxygen intake is not made, that the amount of carbohydrate in the body remained unaltered. The error of this assumption, especially in experiments on fasting, was only too obvious, but not until provision was made for a direct determination of the oxygen consumed was it possible to secure any definite knowledge regarding the changes in the store of glycogen.

The modified form of respiration calorimeter[*] makes it possible to determine not only the metabolism of nitrogenous material, but also the carbon dioxide, water, and heat output and oxygen intake. With the new apparatus and increase in number of determinable factors, a series of experiments to study as completely as possible the metabolism in fasting men was planned. This investigation was made possible by liberal grants of the Carnegie Institution of Washington.

According to the plan of tho experiments, the respiratory exchange and heat output were made the special subjects of study. Experiments during prolonged fasting were included to note the fluctuations in metabolism from day to day, and since the number of subjects available for long fasts was limited, a series of 2-day fasts with a number of men was included to eliminate the influence of individuality. The rapidity and amount of gain of nitrogenous material in the body consequent upon the ingestion of food after a prolonged fast was studied as a closely related supplementary problem.

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[*] Trudi Russkavo obshtshestva okhraneniya Narodnavo Zdravia (1888), 12, pp. 13-76, St. Petersburg.

[*] Dissertation, St. Petersburg (1893).

[*] Zeit. f. physiol. Chemie (1905), 46, p. 440.

[*] Experiments on the metabolism of matter and energy in the human body, 1900-1902. W. O. Atwater & F. G. Benedict. Bull. 136, Office of Experiment Stations, U. S. Department of Agriculture (1903), Washington, D. C.

[*] Carnegie Institution of Washington Publication 42 (1905).

METHOD OF INVESTIGATION.

In any study of metabolism, the greater the number of series of simultaneous observations on the same person, the more nearly does the study approximate completeness. The number of factors which may be determined is limited by the conditions surrounding an experiment, and while the use of the respiration calorimeter enables us to secure data heretofore not attainable, the nature of the apparatus is such as to preclude many physical and psychical observations which might have been obtained on a subject living outside the chamber of the respiration apparatus.

The observations made in these studies naturally divide themselves into four classes—grosser or general observations, and physiological, chemical, and physical measurements. The following sections enumerate the observations themselves and the methods employed in obtaining them.

GROSSER OBSERVATIONS.

In all of the instances of prolonged fasting which have been observed by scientists, certain grosser observations have been made which deal for the most part with the physical appearance, loss in weight, and general mental and physical condition. Such observations were likewise made in connection with the series of experiments here reported, although, as has been pointed out above, they were made, at times, with considerable difficulty.

Body-weight.—By means of the special form of weighing apparatus described in an earlier report,[a] accurate observations on body-weight were possible in all save the first experiment. Use is made of the fluctuation of the body-weight not only to note the condition of the subject but also as a check upon the accuracy of the determinations of intake and output. The total weight of income and the total weight of outgo being known, the difference between them may be determined and should represent body substance gained or lost; this could be readily checked by means of the weights recorded by the special apparatus for obtaining body-weight.

Examination by physician.—In a study of fasting involving abstinence from food for a number of days, it was deemed important to have careful examinations made of the subject from time to time by a skilled physician; consequently it was arranged to have Dr. John E. Loveland, of Middletown, Connecticut, make careful examinations of all the subjects of these experiments, and also to examine the subjects of long experiments on each day of the experiments proper. The observations of the physician were for the most part confined to those obtainable through a glass window and by the telephone, although he could make use of the continuous record of body temperatures obtained during the experiments. Several attempts were made to determine

[a] Carnegie Institution of Washington Publication 42 (1905).

the blood pressure by means of the sphygmomanometer. Since the obliteration of the radial pulse is necessary for the successful determination of the blood pressure, poor success attended its use. In order to enable the attending physician to note the character of the pulse, a provision was made for attaching a thin rubber diaphragm to the wrist of the physician and then inclosing this in the outer end of the food aperture in such a manner that no air could enter or escape. On opening the inner end of the food aperture, the subject could then place his hand in such a manner that the physician could obtain the radial pulse. This procedure, unfortunately, could not be used simultaneously with the sphygmomanometer. It is further to be regretted that the technique of this operation was not completely developed before it was first used, and hence certain slight errors due to leakage of air were unavoidable on one or two occasions. By means of the analysis of the air in the chamber at the end of each day, however, it was possible to correct for the amount of the leak with great accuracy.

PHYSIOLOGICAL MEASUREMENTS.

The same difficulties which attended the making of grosser observations on the subject prevented a thorough series of physiological measurements, such as could be obtained with a subject moving freely about the laboratory. It is very much to be regretted that the observations actually made could not have been amplified and a greater amount of data secured. Fortunately, however, the study of Succi by Luciani was especially complete in observations of this nature, and inasmuch as Succi's fasting experiment lasted for 30 days, it is fair to assume that the data obtained by Luciani could not be greatly amplified by any data secured in an experiment of such short duration as 7 days.

Measurements of body temperature.—In spite of the difficulties of making physiological observations on a subject inclosed in a respiration chamber, it was possible to secure the body temperature of the subject with great accuracy by means of a rectal thermometer, fully described elsewhere.[a] By means of this thermometer, which is on the principle of a bolometer, the variations in electrical resistance of a fine platinum wire inclosed in a pure silver tube and inserted several centimeters in the rectum can be observed at will. While the majority of our subjects have experienced no difficulty in wearing this electrical resistance thermometer for a considerable period of time, the subject of the longer fasting experiments found this difficult and it was only during certain experimental days that he could use the thermometer and insure us normal results. It was deemed inadvisable to urge the use of the thermometer for fear of causing the subject discomfort which might produce abnormal results. In

[a] Archiv f. d. ges. Physiol. (1901), 88, p. 492; Carnegie Institution of Washington Publication 42, p. 156 (1905).

a number of cases where the rectal thermometer was not worn, his temperature was taken, usually in the mouth, by means of a clinical thermometer.

Pulse rate.—As a measure or an index of the degree of internal muscular activity, the pulse and respiration rates are of great value, and consequently in any series of observations which include total heat production it is desirable to have a continuous record, if possible, of the pulse rate and the respiration rate. In the longer fasting experiments here reported, the subjects made observations of their own pulse rate, sometimes as frequently as every half hour. Each subject was instructed to count the radial pulse for upwards of 2 minutes, noting the count during one minute and using the second minute as a check on the first count. Obviously this gave no pulse records during sleep, and this omission seemed so serious that an apparatus for indicating the pulse rate during the whole day was secured.

Through the kindness of Prof. W. T. Porter a Fitz pneumograph[a] was obtained. This pneumograph was adjusted around the chest of the subject and a stout-walled transmission tube used to connect the pneumograph with a glass tube in the inner door of the opening through which food is passed into the chamber. A flexible rubber tubing connected the tube in the inner door with one in the outer door of this compartment, and finally a rubber tube connected the tube in the outer door with a tambour. In spite of this long transmission, a distance of some 3 or 4 meters, the form of tambour used gave excellent results. Prof. W. B. Cannon, of the Harvard Medical School, kindly came to Middletown and assisted in adapting this apparatus to the conditions of experimentation. It was ascertained that when the pneumograph was adjusted carefully over the apex beat of the heart the pulse rate could be very accurately noted. In the earlier tests a curve was traced on smoked paper. It was found later that the curve was unnecessary, since the vibrations of the pointer of the tambour were so marked that the observer could count the respirations without difficulty. This apparatus served its purpose admirably and has resulted in our obtaining many observations of pulse rate during sleep that would have been otherwise unobtainable. During certain of the fasting days, and especially during certain periods of the experimental day, the strength of the pulse seemed to fall off to such an extent that the minor vibrations of the pointer, due to the transmission of the pulse waves, were so small as to be recognized with difficulty. Furthermore, special precautions were necessary to make sure that the pneumograph remained in approximately the position in which it was originally adjusted. For this purpose, two or three straps of canvas were placed over the shoulders to keep the pneumograph from slipping down. Each subject wore the pneumograph continuously throughout the whole

[a] Journ. Experimental Medicine (1896), 1.

experiment and very little, if any, discomfort was experienced from having it about the chest, even during the hours of sleep.

Respiration rate.—In addition to the work of circulation, the work of respiration forms a considerable portion of the total amount of internal muscular work and consequently any accurate data regarding the rate of respiration are of importance in all measurements involving energy transformation. Various attempts have been made previously in this laboratory to secure the rate of respiration of subjects during experiments. By the use of a stop watch the attempt has been made to count the respirations by looking through either the glass window in the front of the chamber or the glass doors of the food compartment. But little success attended these attempts, for the subject moved so frequently that it was impossible to count the rise and fall of the chest for any great length of time. Furthermore, the subject very soon became aware of the fact that the respiration rate was being counted, and the difficulties of counting the rate of respiration when the subject knows that the count is being made are only too well understood by physicians. The pneumograph is ideally adapted for giving the desired data. Indeed, it was extremely fortunate that with the same piece of apparatus two such valuable factors could be measured. When the curve of the respiration was drawn upon smoked paper, there was obviously a superimposed curve of a much smaller amplitude showing the pulse. Singularly enough, it was found that during the waking period, when the subject was more or less actively moving about, more difficulty was experienced in obtaining the respiration rate than the pulse rate; for while the slight vibration of the pointer for each pulse beat could, as a rule, be detected by the observer, the grosser vibrations due to the rise and fall of the chest were frequently masked by fluctuations due to body movements. This was particularly true during the period when meals were eaten. On the other hand, during the night and at times when the pulse rate became very feeble and almost impossible to recognize, it was practically always possible to obtain the respiration rate.

Strength tests.—The importance of securing data regarding the effect of inanition on strength has been recognized heretofore. The observations made by the subject of the experiments of Johansson, Landergren, Sondén, and Tigerstedt,[a] in which the subject noted the length of time he could suspend himself on the arm, were of much value. Unfortunately, with the subject of the prolonged fasts here reported, tests of strength were not included, as the multiplicity of other observations made it difficult to include these in the daily routine. In the later group of experiments, made on different subjects, a series of strength tests was made with the Tiemann hand dynamometer before, during, and after the close of the fast. Inasmuch as the element of fatigue is

[a] Skan. Archiv f. Physiol. (1897), 7, p. 31.

also important, record was kept of all the individual tests. In some of the earlier experiments a trial was made first with the right hand, then with the left hand, again with the right, and then with the left, alternately, until five or six tests with each hand had been made. In the later series five tests were made with the right hand and five with the left. The data secured furnish evidence as to the rapidity of the onset of fatigue as affected by inanition.

Blood examination.—Some of the earlier observations[a] indicated noticeable morphological changes in the composition of the blood, and it seemed desirable to obtain from the subject of these experiments such data as was possible. Accordingly, during some of the prolonged fasts, a number of blood examinations were made. The blood examination consisted of a study of smears and the determination of hemoglobin and the number of leucocytes and erythrocytes per cubic millimeter. During the period before fasting and that after the subject left the calorimeter, no special difficulty was experienced in making these examinations. Since, however, in most of the long fasting experiments, the fasting concluded and the experiment with food began while the subject was still inside the respiration chamber, great difficulty was experienced in securing samples of blood for these tests. In order to obtain blood samples during the calorimeter experiments, a device similar to that arranged for the examination of the subject's pulse by the physician was used. This consisted of a thin sheet of rubber, through the center of which a small hole was cut. A thimble was inserted in this hole and the rubber diaphragm fastened to a frame made by removing the glass from an extra outer door to the food compartment. When this frame was closed, it made an air-tight closure. The subject was instructed to open the inner door of the food compartment, insert his middle finger into the thimble, and then give a sudden thrust. In this manner the finger was accessible to the observer outside of the calorimeter and no air could enter, as the sheet rubber closed tightly about the finger. Obviously this procedure is open to the objection that more or less constriction is placed upon the finger and consequently there may be an abnormality in the blood taken in the sample. As a matter of fact, during the long fast it was extremely difficult to get any blood for the tests and, consequently, they are very incomplete.

CHEMICAL MEASUREMENTS.

The chemical measurements in connection with the metabolism experiments included the chemical analyses of the food, feces, urine, and the respiratory gases. The technique of these examinations has been given in detail elsewhere.[b] It may be briefly referred to here.

[a] Tauszk, loc. cit.

[b] Carnegie Institution of Washington Publication No. 42 (1905); U. S. Dept. of Agr., Office of Experiment Stations, Buls. 44, 63, 69, 109, 136, and 175.

Food, feces, and urine.—Although the object of the experiments here reported was primarily the study of metabolism during fasting, there was opportunity to study the effect of fasting on metabolism when food was given after fasting; hence the chemical examination of food was included in many of the studies here reported.

The chemical determinations made in these experiments included water, ash, nitrogen, carbon, organic hydrogen, ether extract, sulphur, and phosphorus of food and feces. In addition to the above the examination of the urine included determinations of chlorine, phosphoric acid, sulphuric acid, creatine, and creatinine.

Sampling and weighing for analyses.—In so far as possible, the determinations were made on fresh material. This was always the case with foods. With feces a preliminary drying was necessary. This drying was done in a vacuum desiccator. Urine was delivered from carefully calibrated pipettes.

Water.—While formerly the water was determined by noting the loss in weight of the substances when heated at about 100° C., experience in this laboratory has shown that this method is open to criticism. Accordingly, water determinations in this series of experiments were made by the vacuum method.[a]

Ash.—Ash was determined by charring a sample of the dried material, extracting the charred mass with water to remove the more volatile salts, igniting the residue, and evaporating the extract with the residue at very low red heat. The determination of ash has by no means the scientific accuracy of the other determinations made in connection with these experiments, since the composition of the material weighed as ash may vary noticeably with the method of treatment. Arrangements could not be perfected in time to make the determinations of the calcium, magnesium, and potassium, but the crude ash determination is not without value.

Nitrogen.—Nitrogen was determined by the Kjeldahl method, mercury being used to facilitate oxidation and potassium sulphide to destroy the mercurammonium compounds in the distillation. The distillation was carried out in a special form of still.[b]

The accuracy of the nitrogen determinations was very frequently checked by testing one or more materials of known nitrogen content, such as ammonium sulphate, ammonium ferrous sulphate, urea, and uric acid. In such tests the digestion was carried out with the addition of 1 gram of pure sugar, so that the conditions might be identical with those of the regular analyses.

Carbon and hydrogen.—The carbon was determined by the Liebig method, with such modifications as have been found to be practicable from extended

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[a] Benedict & Manning, Am. Jour. Physiol. (1905), 13, p. 309.
[b] Jour. Amer. Chem. Soc. (1900), 22, p. 259.

experience in this laboratory.[39] In the later experiments, the determinations of the carbon in the urine were made by the electrical method of Morse.[40]

The accuracy of these methods of analysis was frequently tested by burning known substances, such as cane sugar or urea.

Ether extract.—The ether extract (crude fat) of food was made by the usual method, by extracting 2 grams of the material (previously dried for the determination of water) in a paper filter pocket and weighing the crude extract thus removed. Feces receive special treatment in the analysis as discussed beyond.

Phosphorus and phosphoric acid.—Total phosphorus in food, feces, and urine was determined by fusion with sodium peroxide and subsequent conversion to magnesium pyrophosphate. The modification suggested by Dubois,[41] which includes the addition of a small amount of sodium carbonate to the fusion mixture, was found to be very satisfactory.

Phosphoric acid in urine was determined, as is usual, by titration with uranium acetate, potassium ferrocyanide being used as an indicator.

Sulphur and sulphuric acid.—The sulphur was determined by fusion with sodium peroxide and sodium carbonate in nickel capsules, precisely as in the case of phosphorus. The sulphuric acid in the fused mass was precipitated as a sulphate by barium chloride and water. The combined inorganic and ethereal sulphates in the urine were determined according to the method of Folin,[42] which consists of heating urine with hydrochloric acid and potassium chlorate and precipitating the sulphate as barium sulphate. An attempt was made to obtain data regarding the neutral sulphur (SO_3) in urine by the difference between the sum of the inorganic and ethereal sulphates (SO_3) and the total sulphur (SO_3). The researches subsequently carried out by Folin[43] on the difficulties of obtaining the precipitates of barium sulphate may tend to lessen the value of the results obtained.

Creatine and creatinine.—The significance of the excretion of creatine and creatinine, as pointed out by Folin,[44] led to the determination of these compounds in the urine of the fasting subjects. The method of Folin for determining creatine and creatinine has been employed in this laboratory. This depends upon the color reaction, noted by Jaffé, produced by the addition of a solution of creatinine to an alkaline solution of picric acid. The depth of color is compared with a half normal solution of potassium bichromate. From the standard color of the normal solution the amounts of creatinine in unknown solutions can readily be obtained.

Chlorine was determined in urine by the Volhardt method.

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[39] Benedict, Elementary organic analysis, Easton, Pennsylvania, 1900.
[40] Amer. Chem. Jour. (1905), 33, p. 591.
[41] Jour. Amer. Chem. Soc. (1905), 27, p. 729.
[42] Amer. Jour. Physiol. (1905), 13, p. 52.
[43] Jour. Biol. Chem. (1906), 1, p. 131.
[44] Amer. Jour. Physiol. (1905), 13, p. 83.

RESPIRATORY PRODUCTS.

For any study of the transformations of matter in the body, complete knowledge of the respiratory products is of the greatest importance. In the experiments here reported, determinations were made not only of the carbon dioxide and of the water-vapor eliminated through the lungs and skin, but likewise of the oxygen absorbed. The apparatus and methods have been described in detail in a previous publication.[a]

Water.—The determination of water, in brief, is as follows: The air-current which leaves the respiration chamber and which contains the water-vapor is caused to pass through a previously weighed vessel containing strong sulphuric acid. The water is retained by the acid and the increase in weight of the vessel indicates the amount of water absorbed during each experimental period, which is usually of from two to three hours' duration. Since there may be noticeable fluctuations in the amount of water in the residual air in the chamber, absolute determinations of the amounts of moisture in this air are made at the end of each period, the differences between the amounts at the beginning and end of each period giving data for correcting the absolute water elimination for that period.

Carbon dioxide.—The determinations of carbon dioxide are made by conducting the air-current from the respiration chamber after it has been freed from water, through vessels filled with soda lime. The carbon dioxide is completely absorbed and provision is made for collecting and weighing the quantity of water lost from the reagent as the dried air passes through it. The soda-lime vessels, as well as the last sulphuric acid-containing vessel, are weighed at the beginning and end of each period. Fluctuations in the quantity of carbon dioxide residual in the air of the chamber are allowed for by analyses immediately after the end of each period and thus the actual carbon dioxide production can be computed accurately.

Oxygen.—The determination of oxygen is somewhat more complex. This gas is inclosed in a highly compressed form in steel cylinders, from which it is admitted to the ventilating air-current. The loss in weight of the cylinder at the end of each period indicates the amount of oxygen admitted. Corrections are made for the slight amounts of nitrogen present in the gas. In addition to the amount of oxygen so admitted, however, there may be very marked fluctuations in the oxygen in the volume of air residual in the chamber, and, consequently, analyses of this residual air are also necessary to ascertain any alterations in the oxygen content. Actual determinations of oxygen from absorption by potassium pyrogallate are made at the end of each day. A system of computation which includes the determination of the apparent volume of the air in the chamber at the end of the period, the amount of carbon dioxide in

[a] Carnegie Institution of Washington Publication No. 42 (1905).

this air, the amount of water-vapor, and the amount of nitrogen enables the amount of oxygen at the end of each experimental period to be computed with great accuracy, and thus obviates the necessity of making the actual analyses with potassium pyrogallate at the end of each period. In general, the agreement between the computed oxygen content and that found by analysis is very satisfactory. The loss in weight of the cylinder, therefore, corrected for storage or loss cf oxygen from the air in the chamber, furnishes data for the computation of the oxygen absorption during any given experimental period.

The measurements of respiratory gases in these experiments include the cutaneous respiration as well as that of the lungs. The nitrogen of perspiration is also determined in many instances.

PHYSICAL MEASUREMENTS.

The physical measurements incidental to experimenting on the transformations of matter and energy in the body consist generally of two kinds, first, the measurement of the potential energy of the food, feces, and urine, and secondly, the measurement of the heat elimination from the body. In certain classes of experiments, where external muscular work is performed, measurements of the heat equivalent of external muscular work are made. The present series, however, consists entirely of rest experiments.

Potential energy of food, feces, and urine.—As a result of many experiments of Rubner, Stohmann, Berthelot, and others, it is possible to compute with reasonable exactness the energy equivalent of food, feces, and urine. Improvements in the technique of the use of the bomb calorimeter, however, have been adopted in this laboratory, and consequently the potential energy of food, feces, and urine were, in every instance, actually measured by means of the calorimetric bomb,[46] in that a dried portion of the material was burned in oxygen under a pressure of 20 atmospheres. In the fasting experiments the determinations were confined to those of the heats of combustion of the urines, and a great deal of experimental work has been done upon this subject. The most elaborate research on the heat of combustion of urine is that published by Farkas and Korbuly.[47] Our experience has been that the most concordant results have been obtained by drying in vacuo 10 to 15 cubic centimeters of urine with 50 mg. of salicylic acid and burning the dried mass. The details of this investigation are not completed. They will be published elsewhere. Unquestionably, the heat of combustion of urine is low rather than high, since it is almost impossible to avoid the loss of ammonia or the conversion of urea into ammonium carbonate, both of which result in a loss of energy. The method outlined above gives results which, in our judg-

[46] Atwater & Snell, Jour. Amer. Chem. Soc. (1903), 25, p. 7.
[47] Archiv f. ges. Physiol. 1904), 104, pp. 564-607.

ment, are at present the best that can be obtained, although it is well recognized by physiologists that the determination of the heat of combustion of urine is one of the most perplexing problems with which we have to deal.

In preparing samples of food and feces for combustion, it is necessary first to partially dry the substance, as otherwise the combustion would be very unsatisfactory. In this partial drying, loss of organic matter, and consequent loss of potential energy, should be avoided. Our experiments with vacuum desiccators have again shown the wisdom of drying physiological preparations and food materials at room temperature in a vacuum rather than at a temperature much above that of the body, i. e., the water-bath or steam-oven.

Heat elimination from the body.—The chamber of the respiration apparatus is provided with appliances for measuring heat. These appliances have been described in detail in a previous publication.[a] The respiration chamber, which consists essentially of an air-tight copper box, is surrounded with alternate layers of air, zinc, and wood, so as to minimize the radiation. The heat produced by the subject is brought away by a current of cold water flowing through a copper pipe, to which a large number of disks are soldered to increase the absorbing surface. Arrangements are made, by heating and cooling the air surrounding the chamber, to render the walls of the chamber adiabatic. By noting the rise of the temperature of the water in passing through the chamber, and the mass of the water, the amount of heat brought away by the water-current can readily be computed. The heat required to vaporize the water given off in the air-current is obtained by multiplying the number of grams of water vaporized by the factor 0.592.

Complete tests of the respiration calorimeter.—Burning known weights of ethyl alcohol in the chamber furnishes a means of checking the accuracy of the respiration calorimeter for measuring water and carbon dioxide output and oxygen intake, as well as heat elimination. A large number of such check tests have given very satisfactory results. In general the quantities actually determined differ from the calculated amounts by less than 1 per cent.

RECORDING RESULTS AND THE USE OF DECIMALS.

In the numerous computations involved in experiments of this nature it is frequently difficult to determine early in the calculation just what degree of refinement in the mathematical calculations is warranted by the accuracy of the experimental process from which the data are derived. Such decision has been withheld in every instance till as late as seemed necessary, in some instances undoubtedly too late, and hence the results are at times expressed with one or two decimal places that are not of real significance. It is to be noted, however, that in the final summary and balance tables supernumerary figures are in general omitted.

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[a] Carnegie Institution of Washington Publication No. 42 (1905).

THE EXPERIMENTAL MAN.

In computing the changes in body-weight, the moisture given off from the man, the changes in body temperature, and consequently fluctuations in total heat produced, and various other factors of a similar nature, theoretically, the man should be without clothing in the chamber; but this is neither practical nor comfortable, and hence the body-weights were, in most instances, taken with the man plus union suit and stockings. This was considered our experimental man. If the body temperature fell 1°, it was assumed that the union suit and the stockings likewise fell 1°. The error seemed almost impossible to avoid, especially with the other discomforts attending on a fasting experiment. However, the exact statement of the conditions in which the weights and measurements were taken is here recorded. It should be said that the average weight of union suit plus stockings has been found to be 483 grams.

PART 2. STATISTICS OF EXPERIMENTS.

The experiments here reported consisted of studies in metabolism during inanition, both on the actual days of the fast and also on days following fast, when food was ingested. Furthermore, in order to throw light on the regaining of nitrogen lost from the body during fasting, two nitrogen metabolism experiments, lasting 25 and 14 days, respectively, were made. The fasting experiments lasted from 2 to 7 days. The experiments with food following fast were of from 1 to 3 days' duration. The subjects were, with the exception of S. A. B., all students in Wesleyan University, nine young men, in good health. S. A. B., with whom the longer experiments were made, was a young "masseur," who had made several fasts prior to his arrival in Middletown with a view of studying his daily losses in weight.

A list of the experiments made in connection with this research is given in table 1.

TABLE 1.—*Duration and character of experiments.*

Metabolism experiment number.	Date.	Subject.	Duration.	Character of experiment.
			Days.	
59	Dec. 18, 19, 20, 1903	B. F. D.	3	Fasting.
68	Apr. 27, 28, 1904	A. L. L.	2	Do.
69	Dec. 16, 17, 18, 19, 1904	A. L. L.	4	Do.
70	Dec. 20, 21, 22, 1904	A. L. L.	3	With food.
71	Jan. 7, 8, 9, 10, 1905	S. A. B.	4	Fasting.
72	Jan. 11, 1905	S. A. B.	1	With food.
73	Jan. 28, 29, 30, 31, Feb. 1, 1905	S. A. B.	5	Fasting.
74	Feb. 2, 3, 4, 1905	S. A. B.	3	With food.
75	Mar. 4, 5, 6, 7, 8, 9, 10, 1905	S. A. B.	7	Fasting.
76	Mar. 11, 12, 13, 1905	S. A. B.	3	With food.
Nitrogen metabolism No. 1	Mar. 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, Apr. 1, 2, 3, 4, 5, 6, 7, 1905	S. A. B.	25	Free selection of food.
77	Apr. 8, 9, 10, 11, 1905	S. A. B.	4	Fasting.
Nitrogen metabolism No. 2	Apr. 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 1905	S. A. B.	14	Free selection of food.
79	Oct. 13, 14, 1905	H. E. S.	2	Fasting.
80	Oct. 27, 28, 1905	C. R. Y.	2	Do.
81	Nov. 21, 22, 1905	A. H. M.	2	Do.
82	Nov. 24, 25, 1905	H. C. K.	2	Do.
83	Dec. 5, 6, 1905	H. R. D.	2	Do.
85	Dec. 9, 10, 1905	N. M. P.	2	Do.
89	Jan. 10, 11, 1906	D. W.	2	Do.

METABOLISM EXPERIMENT NO. 59.

This experiment began December 18, 1903, and continued without interruption for three days.

The subject, B. F. D., was a student in Wesleyan University, of athletic temperament, and active in his movements. Since it is customary for each student at the university to have his body measurements taken, very complete records of the physical characteristics of the subject were available. The anthropometric records are given herewith.

Measurements of B. F. D.—Date, Oct. 20, 1903. Age, 22 years.

Weight ....kilograms..	67.3
Height ....centimeters..	170.3
Length of—	
Sternum ....do....	138
Navel ....do....	98.7
Pubis ....do....	80.7
Sitting ....do....	94.1
Knees ....do....	43.3
Shoulders, elbow........do....	34.3
Elbow to tip............do....	44.2
Arm reach ....do....	107.1
Right foot ....do....	26
Left foot ....do....	25.8
Girth of—	
Head ....do....	55.2
Neck ....do....	37.3
Chest—	
Depressed ....do....	85.4
Inflated ....do....	94.5
Normal ....do....	91
At 9th rib, full........do....	85
At 9th rib, depressed..do....	77.8
Waist ....do....	77.5
Hips ....do....	96
Right biceps ....do....	32.2
Left biceps ....do....	31.9
Right arm ....do....	28.9
Girth of—	
Left arm ....centimeters..	28.7
Right elbow ....do....	25
Left elbow ....do....	25
Right forearm ....do....	28.6
Left forearm ....do....	28.2
Right wrist ....do....	16.1
Left wrist ....do....	16.5
Right thigh ....do....	57
Left thigh ....do....	56
Right knee ....do....	38
Left knee ....do....	37.2
Right calf ....do....	38
Left calf ....do....	37
Right instep ....do....	25.3
Left instep ....do....	24.5
Breadth of—	
Head ....do....	15.2
Neck ....do....	11.3
Shoulders ....do....	37
Chest ....do....	27.7
Waist ....do....	25.2
Hips ....do....	31
Depth of—	
Chest ....do....	16.8
Abdomen ....do....	19.3

No especial preliminary preparation was made by the subject for this experiment, though in some of the later experiments the question of defecation during an experimental period was eliminated by the use of enemata for the removal of fecal matter. Moreover, although fasting experiments of one or two days' duration had previously been made in this laboratory, no regular routine for this type of experiment had been decided upon.

The preparation of a regular program to be followed each day was therefore deemed inadvisable. It was definitely provided, however, that the subject was so to regulate his muscular movements as to have the same amount of activity,

as nearly as possible, on all days of the experiment, and that the times for urinating, rising, weighing, and retiring should be regular. Since previous experience had shown that greater accuracy was obtained in the analyses of the respiratory gases if during the waking hours the subject took special precautions to remain as quiet as possible for the half hour preceding the end of each experimental period, he was cautioned to spend this last half hour of each period in sitting quietly in the chair, reading or writing.

The subject entered the calorimeter chamber during the early evening of December 17. The bedding, urine bottles, feces can, and such books as the subject wished, together with all the articles too large to pass through the food aperture, had been placed in the chamber before the large plate-glass window which closes it was sealed in place.

In addition to a union suit of underwear, stockings, a light sweater, and trousers, the subject wore a pair of heavy-soled shoes primarily designed to prevent the conduction of heat from the soles of the feet to the metal floor of the chamber. Subsequent experience showed that these special shoes are unnecessary.

After entering the respiration chamber, the subject adjusted the rectal thermometer and prepared for his three days' stay in the calorimeter by placing his bedding, books, and other articles in convenient positions on the shelves. Shortly before 11 p. m. he retired for the night, and at 1 a. m. the first preliminary period began. By this time the calorimeter chamber had reached temperature equilibrium and the preliminary air analyses had been made. The absorbing vessels used to purify the air were changed at the end of each experimental period, i. e., every 3 hours. The regular air analyses were made at 7 a. m. daily.

Routine.—The general routine followed during this experiment was as follows: At 7 a. m. the subject rose, dressed, and weighed himself on a platform scale inside the chamber, and then spent the rest of the day sitting or lying down. A considerable portion of each day was occupied with reading. Urine was collected every 3 hours until 10 p. m., after which it was not collected again until 7 a. m. the next day. The muscular movements were restricted to moving about the chamber, caring for the excreta, opening and closing the food aperture, telephoning, and dressing and undressing.

Notes from diary.—No plans for definitely testing the effect of the stay in the respiration chamber on the mental or physical condition of the subjects had been made, since no detrimental results were anticipated. Yet it seemed desirable to obtain some notes concerning the psychical and physical condition of the men as recorded by themselves. For this reason each subject was instructed to keep a diary, in which he was at liberty to record anything he chose

The following are extracts from the diary of B. F. D. during this experiment. They include everything relevant to his physical and mental condition.

Notes from diary.

Dec. 17, 1903:

Entered calorimeter at 10^h35^m p. m.

Dec. 18, 1903:

7 a. m. Arose. During the night I did not sleep very well, though this morning I feel rested and quite refreshed. My strange surroundings were the cause of my not sleeping well. Do not feel uncomfortable and am not hungry.

10 a. m. Feeling a little drowsy and have a slight pain in my head.

11^h55^m a. m. Am feeling all right and think my head is a little better.

1^h50^m p. m. Feeling better; my head is clearer. I could eat, but do not feel any distress.

2^h55^m p. m. My head is aching a little.

4^h10^m p. m. Am at present feeling very well; do not feel hungry and head feels better.

5^h20^m p. m. At present I am not at all hungry and feel better than any time during the day.

5^h50^m p. m. Attempted to defecate.

7^h15^m p. m. Am now feeling well and am not at all hungry.

9 p. m. Beginning to feel a little sleepy.

Dec. 19, 1903:

7 a. m. Arose.

7^h15^m a. m. Slept very well last night and did not wake until 6^h35^m a. m. Do not feel hungry, and in general feel well, except that my head does not seem as clear as usual.

8^h10^m a. m. My head feels much better and clearer; feel so well that I have tried to sing. Not at all hungry.

9^h50^m a. m. Have been sitting since 7 and my head is tired; have been reading and studying.

10^h40^m a. m. Head now feels much better.

11^h45^m a. m. Feel very well.

1^h5^m p. m. My hands feel a little cold, though I am very comfortable and my head feels clear.

2^h5^m p. m. Am feeling well, except a little drowsy.

2^h10^m p. m. Have been thinking of some nice things to eat and find that my appetite responds with double force.

3 p. m. Do not feel like doing anything; my ambition seems to be leaving me. Otherwise I feel very well. My head is all right at present.

4^h10^m p. m. Feeling very well and quite rested.

6^h25^m p. m. Feeling well, but am tired of studying and am lonely.

8^h27^m p. m. Have been writing to pass away time and feel the better for doing it. Feel very well.

Dec. 20, 1903:

7 a. m. Arose.

7^h20^m a. m. Slept pretty well during the night, but woke at 5 and stayed awake until 7; did not sleep as soundly nor as well as the night before. (I want to say for yesterday that whenever I would study hard my head would begin to ache a little. Then when I would rest or do a little reading or writing for amusement my head would soon clear up and again feel fresh. This was especially noticeable when I studied geometry. Yesterday morning, also, there was a slight taste in my mouth, not noticeable this morning.)

7^h30^m a. m. Am feeling well and strong, but rather dull.

8^h5^m a. m. Attempted to defecate.

9 a. m. Am feeling well; no pain in head.

10^h8^m a. m. Have been lying quiet for an hour; am feeling very well, about the same as though I were lying in bed in my room.

10^h47^m a. m. When I read of food my appetite is stimulated.

11^h32^m a. m. Lying down and reading; feeling very well. Am hungry.

12^h15^m p. m. Hunger is not painful.

4^h35^m p. m. Feeling very well.

8^h40^m p. m. Feeling very well; have had no pain in my head to-day. Have felt better to-day than during the past two days.

10^h34^m p. m. Am feeling well, but slightly tired.

Dec. 21, 1903:

7^h5^m a. m. Slept until 2^h30^m this morning, when I awoke and remained awake until some time after 6; then slept until 7. When I awoke at 5 yesterday morning and at 2^h30^m this morning I was very warm, too warm to sleep. Am feeling good; my head is clear and I am not hungry. My mouth is a little dry.

NOTES TAKEN AFTER EXPERIMENT.

When I came out of the calorimeter, at first I felt rather weak, but think this was caused more by being inactive for 3 days than from weakness. Walked to my room, washed, and then walked a short distance. Felt rather hungry.

Ate 1 slice of toast and drank 1 glass of milk; it tasted very good. This made me feel better and stronger and I walked back to my room and shaved. My hands were not unsteady.

Attended recitations at 8^h10^m a. m. and 9 a. m., but felt rather sleepy. At 10 o'clock ate 2 slices of bread and drank a small glass of milk; afterwards felt stronger. Attended recitations till 1 p. m. Felt rather sleepy.

At 1 o'clock went to dinner and ate 3 slices of toast and drank 2 glasses of milk. After dinner, took a slow walk in the open air for over 2 hours. This, though it made my legs a little tired, seemed to refresh me and made me feel much better. Studied from 4^h30^m until 6, when I went for supper. Was hungry and ate all that I wanted, including milk, toast, stewed meat, and 2 dishes of apple-sauce. After supper felt strong and well enough to study until 10^h45^m, when I stopped and took a hot bath and went to bed. Slept very soundly and very well for 8 hours; after that felt no effects of my fast and was strong and well.

Body movements.—Although the subject endeavored to secure uniformity of body movements from day to day, a partial check upon his records of his muscular activity was attempted by securing a more or less complete record of grosser body movements as observed by the physical assistant sitting at the window in the front of the calorimeter. These movements were recorded, often very informally, on the sheets which are used for recording the thermometric observations from which the total heat is computed. These observations of grosser movements were supplemented by the record kept by the chemical assistant of the number of times the food aperture was opened and closed. A list of all recorded body movements follows. In it the imperative mood has been used for the sake of brevity.

Movements of subject.—Duration, three days, from Dec. 18, 7 a. m., to Dec. 21, 7 a. m., 1903.

December 18.					
A. M.		A. M.		P. M.	
$7^h 04^m$	rise, urinate, telephone.	$9^h 48^m$	lie.	$1^h 00^m$	move about.
7 14	weigh.	9 52	sit, telephone.	1 02	urinate.
7 22	write.	9 54	lie.	1 05	food aperture.
7 28	take pulse.	10 04	rise, telephone.	1 28	read.
7 32	read.	10 06	move about, urinate, sit.	1 45	food aperture.
7 36	telephone.	10 15	food aperture.	1 48	write.
7 46	read.	11 06	food aperture.	2 02	telephone.
7 48	telephone.	11 18	lie.	2 22	change position.
7 54	telephone, drink.	11 48	restless.	2 28	read.
8 00	food aperture.[1]	11 50	sit.	2 32	stop reading.
8 12	rise.	11 54	telephone.	3 04	lie, read.
8 14	dress.	11 56	stand.	3 22	stop reading.
8 18	read.	11 58	sit, telephone.	3 28	sit, take pulse.
9 14	telephone.	P. M.		3 32	food aperture.
9 18	lie, read.	$12^h 10^m$	food aperture, read.	3 34	restless.
				3 38	read.
				3 50	telephone.

[1] This term is used in this and all similar tables hereafter without further remark to indicate that the subject goes to the food aperture, opens it, passes out whatever he wishes, takes in anything designed to be received, and closes the food aperture.

***Movements of subject.*—Continued.**

December 18 (cont.)

P. M.

$4^h 05^m$	food aperture.
4 26	telephone.
4 36	food aperture.
4 44	read.
5 44	undress.
5 52	attempt to defecate.
5 54	rise, move vigorously.
5 58	dress.
6 08	lie, read.
6 28	write.
6 46	lie.
7 02	rise, urinate, telephone.
7 04	move about.
7 06	food aperture.
7 08	sit.
7 12	recline.
7 20	read.
7 54	telephone.
7 56	sit.
8 00	move about.
8 06	sit.
8 24	lie.
8 44	recline, read.
8 58	take pulse.
9 04	read.
9 08	sit.
9 12	read.
9 52	recline.
10 00	rise.
10 02	urinate.
10 04	sit, drink, read.
10 06	telephone, food aperture.
10 08	sit, read.
10 48	rise, open bed.
10 56	telephone.
11 00	retire.

December 19.

A. M.

$7^h 00^m$	rise.
7 01	urinate.
7 02	telephone, dress.
7 10	weigh.
7 14	sit, write.
7 20	walk about, food aperture.
7 22	fold bed.
7 28	write.
7 34	read.
7 38	write.
7 48	telephone.
7 52	read, write.
8 02	take pulse.
8 10	sit.
8 12	telephone, food aperture.
$8^h 24^m$	write.
8 26	drink.
8 28	write.
8 34	lie.
8 40	sit.
8 44	write.
8 48	drink.
9 08	write.
9 14	stop writing.
9 22	read.
9 40	telephone.
9 44	read.
10 04	urinate, food aperture.
10 06	lie, read.
10 22	stop reading.
10 34	rise, weigh.
10 36	write.
10 44	read.
10 58	telephone.
11 04	stop reading.
11 12	read.
11 16	recline, read.
11 20	sit.
11 26	recline, read.

P. M.

$12^h 02^m$	food aperture.
12 08	recline, read.
12 36	lie.
1 00	rise.
1 01	urinate.
1 08	lie.
2 08	sit.
2 20	read.
2 36	lie.
2 40	read.
2 58	sit.
3 06	read.
3 26	stop reading, take pulse.
4 04	urinate, food aperture.
4 06	sit.
4 08	food aperture.
4 12	read.
4 18	stand.
4 22	sit.
4 26	read.
4 32	recline.
4 44	take pulse.
4 52	telephone, food aperture.
5 04	sit.
5 12	read.
5 44	recline.
6 06	sit.
6 30	stand.
7 02	telephone, urinate.
7 04	food aperture.
7 12	stand.
$7^h 24^m$	} move about.
7 36	} move about.
7 44	read.
8 14	write.
9 02	food aperture.
9 08	telephone, sit.
9 12	food aperture.
9 14	drink.
9 16	read.
9 34	lie.
10 00	rise, urinate.
10 02	walk.
10 06	sit, read.
10 20	food aperture.
10 42	telephone.
10 54	move, stand.
10 56	undress, etc.
11 00	retire.

December 20.

A. M.

$7^h 00^m$	rise, telephone.
7 01	urinate.
7 04	walk, dress.
7 10	weigh.
7 12	telephone.
7 15	food aperture.
7 16	move about.
7 18	sit.
7 24	write.
7 34	drink.
7 46	take pulse.
7 48	stand.
7 50	food aperture.
7 58	move about.
8 04	move vigorously.
8 08	sit.
8 10	write.
8 16	read.
8 26	recline, take pulse.
8 34	read.
9 00	sit, write.
9 06	recline.
10 04	sit, food aperture.
10 06	sit.
10 08	write.
10 12	recline, read.
10 32	stop reading, rest on elbow, write.
10 36	read.

P. M.

$12^h 10^m$	move about.
12 18	telephone.
12 22	sit at table.
12 25	food aperture.
12 30	lie.
1 04	rise, urinate, sit.
1 06	write.
1 14	move about.

Movements of subject.—Continued.

December 20 (cont.)

Time	Activity
P. M.	
1h 32m	write.
1 34	telephone.
1 44	take pulse.
1 48	recline, read.
2 18	sit.
2 24	recline, read.
2 58	take pulse.
3 24	sit, take pulse.
3 28	lie, read.
4 04	sit, read, write.
4 05	food aperture.
P. M.	
4h 36m	stand, food aperture.
4 40	sit, read.
5 04	read.
6 08	recline.
7 00	rise, telephone.
7 01	urinate.
7 02	walk, sit.
7 10	food aperture.
7 12	sit.
7 16	rise, sit.
7 40	rise.
P. M.	
7h 44m	sit.
8 04	food aperture.
8 08	drink.
8 10	rise, sit.
9 08	rise.
9 24	lie, read.
10 02	sit, rise, urinate.
10 14	telephone.
10 30	food aperture.
10 50	rise.
10 54	undress.
11 00	retire.

Pulse.—B. F. D. took his pulse throughout the experiment at intervals of from 30 to 45 minutes from 7 a. m. to 11 p. m. daily. The pulse was counted for 2 minutes and the average recorded in his diary. The records are tabulated below.

Pulse rate of subject in metabolism experiment No. 59 (December, 1903).

Time.	Rate.			Time.	Rate.		
	Dec. 18.	Dec. 19.	Dec. 20.		Dec. 18.	Dec. 19.	Dec. 20.
7h 20m a.m.	..	61	[1]63	3h 00m p.m.	56	63	66
7 30	64	..	..	3 30	54	60	66
7 50	..	..	64	4 10	59	61	67
8 05	..	57	..	4 40	55	55	67
8 35	..	..	58	5 20	56	..	64
8 50	61	64	..	5 45	..	60	..
9 00	..	..	64	6 00	53	..	68
9 25	57	..	..	6 25	..	60	..
9 40	..	64	..	6 40	58	..	..
10 05	55	..	61	7 05	54	56	64
10 45	55	63	61	7 45	..	63	64
11 15	52	56	..	8 00	55	..	..
11 32	..	..	65	8 27	..	57	..
11 45	55	57	..	8 40	..	..	65
12h 15m p.m.	..	..	62	9 10	46	63	56
12 30	52	..	..	9 40	47	55	..
1 05	55	54	61	10 05	..	50	51
1 50	57	62	66	10 34	50	..	59
2 20	55	..	65	10 51	..	55	..

[1] At 7 a.m. Dec. 21, pulse=67.

Drinking-water.—No attempt was made in the experiments here reported to insist upon complete abstinence by the subject, and consequently drinking-water was allowed whenever desired. A bottle filled with water and previously weighed was passed to the subject through the food aperture. The temperature of the water was taken immediately before it entered the chamber. The amount of water consumed was determined in all cases by deducting from the weight of the bottle plus water at the time it entered the calorimeter the weight of the bottle plus water when it left the chamber. This method takes account of the

small quantities that are necessarily vaporized from the mouth and neck of the bottle. However, for the purpose of heat measurement it is immaterial in this form of calorimeter whether a gram of water is vaporized in the body of the subject or from the neck of the bottle. In this experiment it is not surely known at what definite times water was drunk, or the actual amount consumed at any given time, but the total amount for each 24 hours is known, and from the above data the periods during which the water was consumed and the amount of water have been estimated. Since, as will be seen later, in computing the total heat production for any given period, the amount of drinking-water consumed during that period is a not unimportant factor, these estimates of this amount were necessary.

Save on the first day, no water was consumed after the subject retired and the amounts consumed were not far from the same each day, ranging from a maximum of 1360.2 grams on the second day to 1188.0 grams on the last day. The water furnished was that from the city supply and no allowance was made for salts or organic matter. The analyses of the water as furnished by the State Bacteriological Laboratory shows in parts per million 56 of total solids, 0.028 free and 0.278 of albuminoid ammonia, and 1.90 of chlorine. The amount of water consumed per period and the total amount per day are given in table 2.

TABLE 2.—*Record of water consumed—Metabolism experiment No. 59.*

Date.	Period during which water was consumed.					Total for day.
	7 to 10 a.m.	10 a.m. to 1 p.m.	4 to 7 p.m.	7 to 10 p.m.	10 p.m. to 1 a.m.	
1908.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 18–19.....	400.0	400.0	400.0	.....	142.5	1342.5
Dec. 19–20.....	400.0	400.0	390.7	169.5	.....	1360.2
Dec. 20–21.....	400.0	388.0	.....	400.0	.....	1188.0

URINE.

In order to show the rate of elimination of nitrogenous material during each 24 hours of the fast, the urine was collected in 3-hour periods from 7 a.m. to 10 p.m. It was deemed inadvisable to awaken the subject to collect the urine in 3-hour periods during the night, as previous experience had shown that the subject found it difficult to go to sleep again. The weight in grams, the specific gravity, the reaction, and the total nitrogen (obtained by the Kjeldahl process) of the urine were determined for the different periods. An aliquot of the urine from each period was taken to make a composite sample for the day and a further aliquot of each day's composite sample was combined to make a 3-day composite. In the daily composite samples, determinations of nitrogen and heat of combustion were made, while in the 3-day composite

the determinations consisted not only of nitrogen and heat of combustion, but also of water, carbon, hydrogen of organic matter, and ash. The results of all determinations by periods are given in table 3.

TABLE 3.—*Determinations in urine per period and per day—Metabolism experiment No. 59.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume. (a÷b)	(d) Reaction.	Nitrogen. (e) Proportion.	Nitrogen. (f) Am'nt. (a×e)
1908.		*Grams.*		c. c.		*Per ct.*	*Grams.*
Dec. 18–19.	7 a.m. to 10 a.m.	190.2	1.0230	186	Slightly alkaline..	1.00	1.90
	10 a.m. 1 p.m.	252.2	1.0165	248	Slightly alkaline..	.67	1.69
	1 p.m. 4 p.m.	528.7	1.0070	525	Slightly acid.....	.45	2.38
	4 p.m. 7 p.m.	129.3	1.0220	127	Strongly acid.....	.65	.84
	7 p.m. 10 p.m.	203.7	1.0130	201	Acid.............	.74	1.51
	10 p.m. 7 a.m.	236.7	1.0240	230	....do...........	1.49	3.52
	Total.........	1540.8	....	1517	....	....	11.84
	Total by composite.......	1540.8	1.0160	1517	....	.77	11.86
Dec. 19–20.	7 a.m. to 10 a.m.	87.2	1.0285	85	Strongly acid.....	1.78	1.55
	10 a.m. 1 p.m.	106.2	1.0270	103	Acid.............	1.71	1.82
	1 p.m. 4 p.m.	114.8	1.0240	112	....do...........	1.69	1.94
	4 p.m. 7 p.m.	175.5	1.0225	172	Slightly acid.....	1.28	2.25
	7 p.m. 10 p.m.	96.2	1.0250	94	Acid.............	1.71	1.65
	10 p.m. 7 a.m.	401.9	1.0180	396	....do...........	1.22	4.90
	Total.........	981.8	....	962	....	....	14.11
	Total by composite.......	981.8	1.0210	962	....	1.43	14.04
Dec. 20–21.	7 a.m. to 10 a.m.	111.1	1.0270	108	Acid.............	1.90	2.11
	10 a.m. 1 p.m.	146.8	1.0220	144	....do...........	1.54	2.26
	1 p.m. 4 p.m.	190.2	1.0190	187	....do...........	1.21	2.30
	4 p.m. 7 p.m.	114.0	1.0245	111	....	1.64	1.87
	7 p.m. 10 p.m.	100.4	1.0280	98	....	1.91	1.92
	10 p.m. 7 a.m.	266.4	1.0240	260	....	1.64	4.36
	Total.........	928.9	....	908	....	....	14.82
	Total by composite.......	928.9	1.0230	908	....	1.59	14.77
	Total, 3 days..	3451.5	....	3387	....	....	40.77
	Total composite, 3 days...	3451.5	1.0200	3387	....	1.18	40.73

The accuracy of the nitrogen determinations and the method of taking composite samples is checked by the agreement between the sum of the amounts of nitrogen in the samples for periods and in the composite samples. Thus, on the first day the total amount of nitrogen eliminated, as determined from the total composite sample, was 11.86 grams and the total amount of nitrogen as determined from the 6 periods was 11.84 grams. The nitrogen in the total composite for the 3 days was 40.73 grams, while the nitrogen eliminated for

the sum of the 18 periods was 40.77 grams. Similarly, the determinations of the heat of combustion on the 3-day composite showed 314 calories, while the determination of the daily composites showed that the urine contained 308 calories of energy. In addition to the data in table 3, the total 3-day composite yielded 95.4 per cent of water, 0.87 per cent of carbon, 0.26 per cent of hydrogen in organic matter, and 0.69 per cent of ash. The heat of combustion of the urine per grm was 0.059, 0.108, and 0.119 calorie, respectively, and the total energy of the urine for the 3 days was 91, 106, and 111 calories, respectively.

Weight and composition of urine.—The total amounts of nitrogen, carbon, hydrogen in organic matter, oxygen, water, solids, ash, and organic matter excreted per day are shown in table 4. The records given in table 3 show that only the determinations of nitrogen and heat of combustion were made daily, the determinations for water, ash, carbon, and hydrogen being made upon the 3-day composite. In accordance with our previous custom, the amounts of carbon and hydrogen were apportioned between the 3 days according to the amounts of nitrogen excreted, it being assumed that a definite amount of nitrogen will carry with it a proportionate amount of carbon and hydrogen in organic matter.

Method of proportioning ash of urine.—Since in this experiment the analysis of ash was made only on the 3-day composite of the urine, it became necessary, in order to obtain the material katabolized from the body for each individual day, to apportion this ash among the different days of the experiment.

The results of subsequent experiments in which the total solids, ash, and nitrogen were determined daily showed that in fasting experiments the ratio of the nitrogen to the total solids is fairly constant, and that on the average N = total solids × 0.29. This percentage was applied to the nitrogen found in experiment No. 59, and the following results for total solids were obtained: For the first day, 40.9 grams; for the second day, 48.4 grams; and for the third day, 50.9 grams—a total of 140.2 grams. The actual total solids were determined in the 3-day composite sample and found to be 158.8 grams, a result 18.6 grams greater than the amount computed for the 3 days. For lack of a better method of apportionment, this discrepancy was distributed over the 3 days in proportion to the several amounts of solids. The estimated amount of total solids for the first day (40.9 grams) was therefore increased by a certain proportion of the total discrepancy corresponding to the fraction $\frac{40.9}{140.2} \times (158.8 - 140.2)$. Apportioning this error, 18.6 grams, over the 3 days by the method indicated above, the corrected total solids are 46.3, 54.8, and 57.7 grams. They are recorded in line *c* of table 4.

The total solids consist of ash, urea, and other compounds which may be

designated "material other than urea." The urea may roughly be computed[1] by dividing the number of grams of nitrogen eliminated by 46.6, the percentage of nitrogen in urea. For the 3 days of this experiment it was computed to be 25.43, 30.15, and 31.70 grams for the respective days. Given, then, the total solids of urine and the number of grams of urea (obtained by dividing the nitrogen by 46.6), by subtracting from the total solids of urine the number of grams of urea, the "material other than urea plus ash" is obtained.

Thus on the first day of the experiment the amount of total solids was computed to be 46.3 grams. Deducting from this the amount of urea for the first day, i. e., 25.43 grams, leaves 20.87 grams as the weight of "material other than urea plus ash." The corresponding figures for the second and third days are 24.65 grams and 26.00 grams. Assuming, then, that the "material other than urea" is constant, the ash is obtained as follows: Total

TABLE 4.—*Weight and composition of urine—Metabolism experiment No. 59 (December, 1903).*

	Dec. 18-19.	Dec. 19-20.	Dec. 20-21.	Total for 3 days.
	Grams.	*Grams.*	*Grams.*	*Grams.*
(*a*) Weight	1540.8	981.8	928.9	3451.50
(*b*) Water	1494.5	927.0	871.2	3292.7
(*c*) Solids, *a*—*b*	46.3	54.8	57.7	158.8
(*d*) Ash[1]	6.94	8.20	8.67	23.81
(*e*) Organic matter, *c*—*d*	39.36	46.60	49.03	134.99
(*f*) Nitrogen	11.84	14.11	14.82	40.77
(*g*) Carbon	8.71	10.40	10.92	30.03
(*h*) Hydrogen in organic matter	2.60	3.11	3.26	8.97
(*i*) Oxygen (by difference) in organic matter, $e-(f+g+h)$	16.21	18.98	20.03	55.22

[1] The ash and water for the individual days are calculated as shown on p. 28. Hence the amounts of solids and organic matter for the individual days are not determined but calculated.

"material other than urea plus ash" for 3 days is to the "material other than urea plus ash" for any given day as the total ash is to the ash for any given day. Thus, the sum of the "material other than urea plus ash" for the 3 days is $20.87 + 24.65 + 26.00 = 71.52$ grams. The proportion, then, would be 71.52 : 20.87 : : 23.81 (total ash determined for the three days of the experiment) : 6.94 grams, the amount of ash for the first day. By means of this proportion the values for ash for the two following days were found to be 8.20 and 8.67 grams, respectively.

Method of obtaining water in urine in experiment No. 59.—The amount of water of the urine was determined on the 3-day composite in this experiment. In order to compute the amounts excreted each day, the figures for the total amount of urine for each day were decreased by the corrected amount of total

[1] It is known that probably at least 1 gram of creatinine is excreted aside from the urea. Hence the calculation is at best but approximate.

solids found by the method explained above. Thus 1540.80 (the amount of urine for the first day) — 46.3 = 1494.50, the water for the first day. Corresponding amounts for the other two days of the experiment were 927.00 grams and 871.20 grams.

ELIMINATION OF WATER-VAPOR.

The amounts of water-vapor in the ventilating air-current are of value to show the loss of water from the body through the lungs and skin, to interpret the hygrometric conditions, and to aid in computing the heat production.

The data regarding the water in the ventilating air-current are given in detail in table 5. Column *a* of the table shows the relative humidity of the air inside the chamber. These data are important, since it is conceivable that there may be noticeable differences in the gaseous exchange and heat radiation as the result of differences in hygrometric conditions. The method of obtaining the figures is as follows: Knowing the total volume of air in the chamber to be approximately 4900 liters and the temperature about 20° C. and that 1000 liters of air when saturated at 20° contain 17.118 grams of water, it is possible to compute the amount of water-vapor which would be present in the air of the chamber if it were completely saturated at 20°. This amount would be 83.88 grams. From the ratio between this saturation amount and the actual amount of water found, the relative humidity is readily obtained. In presenting the results of subsequent experiments in this report the relative humidity will not be given, but the weight of water-vapor in grams at the end of each period, as shown in column *b* of table 5, will be included in the tables. By following the method outlined above, the relative humidity can by simple computation be readily obtained. In column *c* is recorded the gain or loss of water-vapor by the air in the chamber from period to period.

At the end of each experimental period, the determination of the amount of moisture in the air is made by weighing the water absorbed from a known amount of air in its passage through a U-tube containing pumice stone drenched with sulphuric acid. The total amounts of water-vapor remaining in the chamber as computed from this determination are recorded in column *b*. The total water of respiration and perspiration, i. e., the amounts retained in the sulphuric acid absorber and recorded in column *d* corrected for the variations in the amount of water-vapor inside the chamber, are recorded in the last column. In subsequent experiments, only the figures recorded in column *b* and column *e* in this table will be presented. In certain experiments other corrections are necessary for the amount of water condensed by the heat-absorbing system and for the differences in weight of the underclothing, chair, bed, bedding, etc. In the experiment here reported, however, no perceptible moisture was observed on the absorbers in the chamber, and the data for fluctuations in the weight of the bed, bedding, and clothing were not obtained.

A word regarding the relative humidity of the air inside the chamber should be said here. The data of table 5 show that, on the whole, the relative humidity falls off somewhat as the experiment progresses, averaging not far from 45 per cent during the 3 days. During work experiments, the humidity increases considerably. It is important to note that during this experiment the air was relatively dry. In the fasting experiments there was no sensible perspiration observed by any of the subjects.

TABLE 5.—*Record of water of respiration and perspiration—Metabolism experiment No. 59.*

Date.	Period.	Water-vapor in chamber at end of period. (a) Relative humidity.	Water-vapor in chamber at end of period. (b) Amount.	(c) Gain (+) or loss (—) from preceding period.	(d) Amount in outgoing air.	(e) Total water of respiration and perspiration. (c+d)
1903.		*Per ct.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
	Preliminary.........	54.8	45.88	....	....	....
Dec. 18......	1 a.m. to 4 a.m..	48.8	40.86	−5.02	130.63	125.61
	4 a.m. 7 a.m..	49.1	41.11	+0.25	132.95	133.20
Dec. 18–19...	7 a.m. to 10 a.m..	51.7	43.25	+2.14	134.27	136.41
	10 a.m. 1 p.m..	49.0	41.05	−2.20	132.21	130.01
	1 p.m. 4 p.m..	47.2	39.55	−1.50	121.14	119.64
	4 p.m. 7 p.m..	48.2	40.38	+0.83	132.91	133.74
	7 p.m. 10 p.m..	45.8	38.37	−2.01	116.35	114.34
	10 p.m. 1 a.m..	43.2	36.19	−2.18	119.05	116.87
	1 a.m. 4 a.m..	44.9	37.55	+1.36	114.05	115.41
	4 a.m. 7 a.m..	46.0	38.54	+0.99	114.91	115.90
	Total............	....	....	−2.57	984.89	982.32
Dec. 19–20...	7 a.m. to 10 a.m..	48.3	40.39	+1.85	122.62	124.47
	10 a.m. 1 p.m..	44.2	37.01	−3.38	125.35	121.97
	1 p.m. 4 p.m..	44.0	36.84	−0.17	115.15	114.98
	4 p.m. 7 p.m..	40.5	33.87	−2.97	123.88	120.91
	7 p.m. 10 p.m..	44.5	37.27	+3.40	118.28	121.68
	10 p.m. 1 a.m..	42.2	35.32	−1.95	117.10	115.15
	1 a.m. 4 a.m..	42.6	35.66	+0.34	111.19	111.53
	4 a.m. 7 a.m..	49.2	41.19	+5.53	115.73	121.26
	Total............	....	....	+2.65	949.30	951.95
Dec. 20–21...	7 a.m. to 10 a.m..	42.6	35.71	−5.48	125.08	119.60
	10 a.m. 1 p.m..	43.8	36.70	+0.99	119.63	120.62
	1 p.m. 4 p.m..	42.8	35.81	−0.89	120.23	119.34
	4 p.m. 7 p.m..	43.7	36.57	+0.76	113.35	114.11
	7 p.m. 10 p.m..	43.1	36.04	−0.53	119.96	119.43
	10 p.m. 1 a.m..	40.7	34.05	−1.99	113.24	111.25
	1 a.m. 4 a.m..	46.5	38.94	+4.89	117.09	121.98
	4 a.m. 7 a.m..	44.7	37.45	−1.49	118.31	116.82
	Total............	....	....	−3.74	946.89	943.15

ELIMINATION OF CARBON DIOXIDE.

Carbon dioxide is one of the most important products of oxidation in the body. Hence determinations of this factor were made in all the experiments

here reported. The details of the determinations for the different periods of this experiment are given in table 6. The ventilation conditions are here considered in detail, since the air is distinctly abnormal so far as its carbon

TABLE 6.—*Record of carbon dioxide—Metabolism experiment No. 59.*

Date.	Period.	Carbon dioxide. In chamber at end of period. (a) Parts in 10,000.	(b) Am'nt.	(c) Gain (+) or loss(−) from preceding period.	(d) Am'nt absorbed from outcoming air.	(e) Corrected weight exhaled by subject (c+d).	(f) Volume exhaled by subject (e×0.5091)	(g) Carbon in carbon dioxide exhaled (e×3/11)
1908.			*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
	Preliminary.....	36	33.37	....	....	....	....	....
Dec. 18....	1 a.m. to 4 a.m.	28	25.82	− 7.55	77.23	69.68	35.47	19.00
	4 a.m. 7 a.m.	35	32.39	+ 6.57	72.39	78.96	40.20	21.54
Dec. 18–19..	7 a.m. 10 a.m.	44	40.72	+ 8.33	93.43	101.76	51.80	27.75
	10 a.m. 1 p.m.	56	51.29	+10.57	78.25	88.82	45.24	24.22
	1 p.m. 4 p.m.	49	44.99	− 6.30	94.59	88.29	44.95	24.08
	4 p.m. 7 p.m.	88	81.72	+36.73	61.85	98.58	50.19	26.89
	7 p.m. 10 p.m.	63	58.79	−22.93	104.63	81.70	41.59	22.28
	10 p.m. 1 a.m.	41	38.43	−20.36	94.48	74.12	37.74	20.21
	1 a.m. 4 a.m.	26	24.60	−13.83	79.12	65.29	33.24	17.80
	4 a.m. 7 a.m.	45	42.12	+17.52	54.47	71.99	36.65	19.63
	Total........	....	....	+ 9.73	660.82	670.55	341.40	182.86
Dec. 19–20..	7 a.m. to 10 a.m.	41	38.11	− 4.01	98.97	94.96	48.35	25.90
	10 a.m. 1 p.m.	32	29.80	− 8.31	94.24	85.93	43.75	23.43
	1 p.m. 4 p.m.	38	34.84	+ 5.04	78.31	83.35	42.43	22.73
	4 p.m. 7 p.m.	37	33.83	− 1.01	89.46	88.45	45.03	24.12
	7 p.m. 10 p.m.	42	38.85	+ 5.02	85.72	90.74	46.19	24.75
	10 p.m. 1 a.m.	31	28.80	−10.05	82.13	72.08	36.69	19.66
	1 a.m. 4 a.m.	25	22.77	− 6.03	71.91	65.88	33.54	17.97
	4 a.m. 7 a.m.	42	38.39	+15.62	61.93	77.55	39.48	21.15
	Total........	....	....	− 3.73	662.67	658.94	335.46	179.71
Dec. 20–21..	7 a.m. to 10 a.m.	34	30.48	− 7.91	103.76	95.85	48.80	26.14
	10 a.m. 1 p.m.	46	41.98	+11.50	72.05	83.55	42.53	22.79
	1 p.m. 4 p.m.	35	31.39	−10.59	96.34	85.75	43.66	23.38
	4 p.m. 7 p.m.	51	45.71	+14.32	69.88	84.20	42.87	22.96
	7 p.m. 10 p.m.	36	31.84	−13.87	100.24	86.37	43.97	23.55
	10 p.m. 1 a.m.	44	38.89	+ 7.05	67.07	74.12	37.73	20.21
	1 a.m. 4 a.m.	37	32.83	− 6.06	79.33	73.27	37.30	19.98
	4 a.m. 7 a.m.	46	41.73	+ 8.90	58.23	67.13	34.18	18.31
	Total........	....	....	+ 3.34	646.90	650.24	331.04	177.32

dioxide content is concerned. In the first column the carbon dioxide is expressed in parts per 10,000.

With variations in muscular activity there are variations in the amounts of carbon dioxide in the chamber at the end of different periods. These variations, expressed as gains or losses, are given in column *c*. The major

portion of the carbon dioxide in the ventilating air-current is absorbed in the soda-lime cans or purifiers. The amount so absorbed is recorded in column *d*. The amount exhaled by the subject, i. e., the amount actually produced during any period, is the algebraic sum of columns *c* and *d*. These amounts are recorded in column *e*. Since the volumes of the carbon dioxide are used in computing the respiratory quotients, they are calculated by multiplying the figures in column *e* by the factor 0.5091 and the results are recorded in column *f*. Column *g* records the amounts of carbon in carbon dioxide exhaled. These values are used in subsequent calculations affecting the gain or loss of chemical elements in the body.

When it is remembered that normal air contains from 3 to 4 parts of carbon dioxide per 10,000, the data in column *a* of the table appear of peculiar interest. The results serve to show that the carbon dioxide content of the air in this experiment was in general from 8 to 10 times that of normal air, and in one instance, at 7 p. m., December 18, it reached more than 20 times the normal.

The amount of carbon dioxide remaining in the chamber at the end of each period is determined simultaneously with the amount of water by absorbing the carbon dioxide from the known volume of air passed through soda lime. The ratio of the total volume of the sample to the volume of air in the calorimeter chamber being known, the amount of residual carbon dioxide can be computed. The amount of carbon dioxide, in parts per 10,000, can in all cases be roughly approximated by multiplying the residual amount in grams of carbon dioxide by 1.12, hence in subsequent experiments the ventilation conditions will not be expressly tabulated.

OXYGEN CONSUMED.

The rôle played by oxygen in katabolism is a complex one, in that all three components of the body, namely, protein, fat, and glycogen, are oxidized in the process of katabolism. The amount of oxygen absorbed during the oxidation is of great importance in interpreting the kinds and amounts of body materials oxidized. While in the case of carbohydrates oxygen is used to oxidize only carbon, since hydrogen and oxygen in the carbohydrate molecule exist in the proportion to form water, with fat and protein, on the other hand there is oxidation of both carbon and hydrogen. Hence the ratio of the oxygen consumed to the carbon dioxide exhaled is markedly different with the three groups of compounds.

For the proper interpretation, therefore, of the specific katabolism, a knowledge of the amount of oxygen absorbed is essential. In these experiments the amount thus absorbed is determined by noting the loss in weight of a steel cylinder from which oxygen is admitted to the ventilating system from time to time, and also any drafts upon the residual amount of oxygen in the air

of the chamber. There are about 1000 liters of oxygen in the air of the chamber at the beginning of the experiment. The subject can draw upon this residual for oxygen to support the vital processes and these drafts would of necessity result in a difference in the composition of the air and the residual amounts of the elements in it. Furthermore, the supply of oxygen admitted may at times be larger than that actually consumed by the subject and hence the residual amount of oxygen may increase.

A reference to the original description of the methods and appliances for the methods of determining oxygen[1] will show that the amount of oxygen supplied varies with the barometric pressure. The admission of oxygen is determined by the height of the rubber diaphragms on the two pans which equalize the pressure of the air. If the barometer falls, the air in the chamber expands, thus causing the rubber diaphragms to rise, consequently decreasing the admission of oxygen during this period. The oxygen is being consumed out of the air and a minimum amount is being supplied. Thus there is a draft upon the residual quantity of oxygen. If the barometer rises the air inside the chamber is compressed and diminishes in volume, resulting in a lowering of the diaphragm on the pans. It becomes necessary, therefore, to so increase the supply of oxygen as to keep the rubber diaphragm from touching the bottom of the pans and thus eliminate any chance for a rarefaction inside the chamber. Under these conditions the oxygen supplied to the chamber may be much greater than that actually required by the subject and the residual amount be thereby considerably increased.

The determinations of the actual amounts of oxygen admitted to the system and the variations in the residual amounts are recorded in table 7. Column *a* records the per cent of oxygen in the air in the calorimeter chamber at the end of each period, and the actual amount expressed in liters is tabulated in column *b*. These amounts were obtained as a result of the analysis of air at 7 o'clock each morning and the computation of the amount of oxygen, which takes into consideration the amount of water-vapor and carbon dioxide as determined by the residual analysis, the amount of nitrogen added with the oxygen, and the total air of the chamber. The only factor that is not shown is the true volume of air inside the apparatus at the end of each period. While this volume is in general not far from 4890 liters, there may be slight fluctuations in volume, due to the size of the subject and number of miscellaneous articles inside the chamber. From these data the amounts of oxygen remaining in the chamber at the end of each period were readily computed.[2]

During the period from 4 to 7 a. m. on December 18, the preliminary night, the increase in the amount of oxygen residual in the chamber amounted to

[1] Carnegie Institution of Washington Publication No. 42.
[2] For a detailed explanation of the method of computation, see U. S. Dept. Agr., Office of Exp. Sta. Bul. 175.

9.80 liters. On the contrary, during the period from 4 to 7 a. m. on the experimental day, December 19-20, there was a decrease of 39.10 liters in the amount of oxygen in the chamber. These and similar fluctuations in the residual amount of oxygen are recorded in column *c*.

TABLE 7.—*Record of oxygen—Metabolism experiment No. 59.*

Date.	Period.	Oxygen.						
		In chamber at end of period.		Gain (+) or loss (−) from preceding period.		(*e*) Am'nt admitted to chamber.	(*f*) Corrected am'nt consumed by subject (*e*—*d*).	(*g*) Volume of oxygen consumed (*f*×0.7).
		(*a*) Proportion.	(*b*) Am'nt.	(*c*) Volume.	(*d*) Weight (*c*÷0.7).			
1908.		*P. ct.*	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*
	Preliminary......	20.6	958.56	....	....	....	....	....
Dec. 18.....	1 a.m to 4 a.m.	20.9	979.32	+ 20.76	+ 29.66	88.53	58.87	41.21
	4 a.m. 7 a.m.	21.1	989.12	+ 9.80	+ 14.00	84.44	70.44	49.31
Dec. 18-19..	7 a.m. to 10 a.m.	21.1	992.97	+ 3.85	+ 5.50	100.88	95.38	66.73
	10 a.m. 1 p.m.	21.0	985.30	− 7.67	− 10.96	68.70	79.66	55.76
	1 p.m. 4 p.m.	21.3	1002.80	+ 17.50	+ 25.00	99.64	74.64	52.25
	4 p.m. 7 p.m.	21.1	998.20	− 4.60	− 6.57	90.03	96.60	67.63
	7 p.m. 10 p.m.	20.9	991.09	− 7.11	− 10.16	75.48	85.64	59.95
	10 p.m. 1 a.m.	21.4	1017.27	+ 26.18	+ 37.40	106.62	69.22	48.46
	1 a.m. 4 a.m.	21.5	1019.72	+ 2.45	+ 3.50	66.85	63.35	44.35
	4 a.m. 7 a.m.	21.3	1010.26	− 9.46	− 13.52	51.46	64.98	45.49
	Total.........	....	....	+ 21.14	+ 30.19	659.61	629.42	440.62
Dec. 19-20..	7 a.m. to 10 a.m.	21.1	1003.45	− 6.81	− 9.73	92.79	102.52	71.76
	10 a.m. 1 p.m.	21.1	1000.07	− 3.38	− 4.83	67.69	72.52	50.76
	1 p.m. 4 p.m.	20.9	988.56	− 11.51	− 16.44	61.29	77.73	54.41
	4 p.m. 7 p.m.	20.8	982.46	− 6.10	− 8.71	71.46	80.17	56.12
	7 p.m. 10 p.m.	20.4	962.49	− 19.97	− 28.53	61.03	89.56	62.69
	10 p.m. 1 a.m.	20.3	951.44	− 11.05	− 15.79	52.48	68.27	47.79
	1 a.m. 4 a.m.	20.0	936.32	− 15.12	− 21.60	42.49	64.09	44.86
	4 a.m. 7 a.m.	19.3	897.22	− 39.10	− 55.86	18.52	74.38	52.07
	Total.........	....	....	−113.04	−161.49	467.75	629.24	440.46
Dec. 20-21..	7 a.m. to 10 a.m.	19.4	899.01	+ 1.79	+ 2.56	100.58	98.02	68.61
	10 a.m. 1 p.m.	19.0	874.42	− 24.59	− 35.13	47.60	82.73	57.91
	1 p.m. 4 p.m.	18.1	826.98	− 47.44	− 67.78	28.23	96.01	67.21
	4 p.m. 7 p.m.	17.4	792.36	− 34.62	− 49.46	30.38	79.84	55.89
	7 p.m. 10 p.m.	17.7	803.91	+ 11.55	+ 16.50	100.98	84.48	59.14
	10 p.m. 1 a.m.	17.7	806.36	+ 2.45	+ 3.50	74.92	71.42	49.99
	1 a.m. 4 a.m.	17.9	815.61	+ 9.25	+ 13.21	90.76	77.55	54.29
	4 a.m. 7 a.m.	18.1	830.12	+ 14.51	+ 20.73	76.78	56.05	39.24
	Total.........	....	....	− 67.10	− 95.87	550.23	646.10	452.28

Since weights rather than volumes are employed in many of the computations, the equivalent in grams of the volume of oxygen lost or gained to the residual air is computed by dividing the volume by the factor 0.7, and recorded in column *d*. The actual weight of oxygen admitted to the chamber from the

steel cylinder is obtained by noting its loss in weight, making due allowance for the nitrogen contained in the compressed oxygen. The weights of oxygen admitted are recorded in column *e*.

Since these amounts do not represent the quantities actually consumed by the subject, they have been corrected for the changes in the residual amounts. The correct amounts consumed by the subject are recorded in grams in column *f* and in liters in column *g*, since the volume absorbed is of importance in subsequent computations.

TABLE 8.—*Elements katabolized in the body—Metabolism experiment No. 59.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Dec. 18, 1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	629.42	....	....	....	629.42	....
Outgo:						
Water in urine.............	1494.50	....	....	167.23	1327.27	....
Solids in urine..............	46.30	11.84	8.71	2.60	16.21	6.94
Water of respiration [1].......	982.32	....	....	109.92	872.40	....
Carbon dioxide.............	670.55	....	182.86	....	487.69	....
Total....................	3193.67	11.84	191.57	279.75	2703.57	6.94
Loss.....................	2564.25	11.84	191.57	279.75	2074.15	6.94
Second day, Dec. 19, 1903.						
Income: Oxygen from air.......	629.24	....	....	....	629.24	....
Outgo:						
Water in urine.............	927.00	....	....	103.73	823.27	....
Solids in urine..............	54.80	14.11	10.40	3.11	18.98	8.20
Water of respiration [1].......	951.95	....	....	106.52	845.43	....
Carbon dioxide.............	658.94	....	179.71	....	479.23	....
Total....................	2592.69	14.11	190.11	213.36	2166.91	8.20
Loss.....................	1963.45	14.11	190.11	213.36	1537.67	8.20
Third day, Dec. 20, 1903.						
Income: Oxygen from air.......	646.10	....	....	....	646.10	....
Outgo:						
Water in urine.............	871.20	....	....	97.49	773.71	....
Solids in urine..............	57.70	14.82	10.92	3.26	20.03	8.67
Water of respiration [1].......	943.15	....	....	105.54	837.61	....
Carbon dioxide.............	650.24	....	177.32	....	472.92	....
Total....................	2522.29	14.82	188.24	206.29	2104.27	8.67
Loss	1876.19	14.82	188.24	206.29	1458.17	8.67

[1] Includes also water of perspiration.

MATERIAL KATABOLIZED IN THE BODY.

In fasting experiments, aside from the isolated instances of anabolic transformations, the transformations of matter are wholly katabolic, that is, the body is losing substance continually. In the fasting experiments here reported the income consisted solely of drinking-water and oxygen of the air. Of these two, oxygen alone is capable of entering into chemical combination. Using the chemical analyses of the urine and the measurements of carbon dioxide and

water output and oxygen intake, it is possible to strike a complete balance of intake and outgo. Such a balance may for convenience be tabulated in the form shown in table 8. The income, which on the first day amounted to 629.42 grams of oxygen, is small as compared with the total outgo, which amounted to 3193.67 grams of material. The outgo is subdivided into water of urine, solids of urine, water of respiration and perspiration, and carbon dioxide.

In considering this table, it should further be stated that there were no feces passed during the time of this experiment, and moreover it was impossible to separate any feces which could with any certainty be designated "fasting feces." For this reason the question of the status of feces in connection with this table is eliminated.

From the chemical composition of water and carbon dioxide and the chemical analysis of the solids in urine, it is possible to compute the amounts of the different elements involved in the katabolic transformations. Thus, the 1494.5 grams of water in the urine of the first day can be subdivided into 167.23 grams of hydrogen and 1327.27 grams of oxygen. In the case of solids in urine we have, from the chemical analyses, 11.84 grams of nitrogen, 8.71 grams of carbon, 2.6 grams of hydrogen of organic matter, 16.21 grams of oxygen, and 6.94 grams of ash, the ash here being treated as an element. The amounts of carbon and oxygen in carbon dioxide are also shown, together with the total outgo in terms of nitrogen, carbon, hydrogen, oxygen, and ash. By deducting the oxygen of the intake, a total loss to the body of 2564.25 grams of material is obtained, of which the larger part is obviously oxygen derived from the water of respiration and carbon dioxide and water in the urine. A similar computation for the second and third days shows losses to the body of 1963.45 grams and 1876.19 grams of material, respectively. From these losses of the chemical elements it is possible to compute the losses of compounds. The computations are based upon the chemical analyses of body protein, body fat, and glycogen. For body protein, the work of Koehler[4] has been taken. For body fat, the analyses of human fat in this laboratory are used,[5] and the carbohydrates existing in the body are assumed to be chiefly glycogen. The following is a tabular statement of the composition assumed in these computations:

Body material.	N.	C.	H.	O.	Mineral matters (including S).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Proteids	16.67	52.80	7.00	22.00	1.53
Fat	....	76.10	11.80	12.10	....
Carbohydrates	....	44.40	6.20	49.40	....
Water	....	....	11.19	88.81	....

[4] Zeit. f. physiol. Chemie (1901), 31, 498.
[5] Benedict & Osterberg, Amer. Jour. Physiol. (1900), 4, p. 74.

Disregarding the mineral matters, the following equations may be derived from these data, letting p = protein, t = fat, r = carbohydrates, and w = water:

$$0.1667p = N$$
$$0.4440r + 0.7610t + 0.5280p = C$$
$$0.1119w + 0.0620r + 0.1180t + 0.0700p = H$$
$$0.8881w + 0.4940r + 0.1210t + 0.2200p = O$$

Solving these equations in terms of N, C, H, and O, the following formulæ are obtained:

Protein	= 6.0 N.
Fat	= 0.005 C + 9.693 H − 1.221 O − 2.476 N.
Carbohydrates	= + 2.243 C − 16.613 H + 2.093 O − 2.892 N.
Water	= − 1.248 C + 7.920 H + 0.128 O + 0.460 N.

The quantities of each element lost from the body, expressed in grams in table 8, may be substituted in these equations for the chemical elements N, H, O, and C. For purposes of illustration the computation of the losses of body compounds for the first day of experiment 59 are given in some detail in table 9.

TABLE 9.—*Illustrative table showing elements and material katabolized in body—Metabolism experiment No. 59.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Dec. 18, 1903	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	629.42	....	....	....	629.42	....
Outgo:						
Water in urine.............	1494.50	....	....	167.23	1327.27	....
Solids in urine..............	46.30	11.84	8.71	2.60	16.21	6.94
Water of respiration[1].......	982.32	....	....	109.92	872.40	....
Carbon dioxide.............	670.55	....	182.86	....	487.69	....
Total..................	3193.67	11.84	191.57	279.75	2703.57	6.94
Loss....................	2564.25	11.84	191.57	279.75	2074.15	6.94
Katabolized body material:						
Protein..................	71.04	11.84	37.51	4.97	15.63	1.09
Fat......................	150.72	....	114.70	17.78	18.24	....
Glycogen.................	89.16	....	39.59	5.53	44.04	....
Water....................	2247.48	....	....	251.49	1995.99	....
Ash......................	5.85	....	....	....	....	5.85
Total..................	2564.25	11.84	191.80	279.77	2073.90	6.94

[1] Includes also water of perspiration.

As a mathematical verification of these computations the results are expressed in tabular form, and by use of the percentage composition shown above the amounts of nitrogen, carbon, hydrogen, and oxygen in the quantities of each compound lost may be recomputed. The sum of the different elements should

then equal the original quantities of elements lost. The mathematical verification of these computations is shown in table 9.

Two features of this table demand special discussion. In the first place, while the actual amount of ash determined by chemical analyses is seen in table 4 to have been 6.94 grams,[a] here it is seen that only 5.85 grams of ash were katabolized. On the other hand, it must be borne in mind that in the 71.04 grams of protein katabolized there were 1.09 grams of ash, since protein contains 1.53 per cent of mineral matter. It is necessary, therefore, to deduct from the total amount of ash in the output, 6.94 grams[a] in this particular experiment, the total amount of ash in the protein, 1.09 grams, since the ash of the katabolized protein appears in the urine. Therefore the difference, 5.85 grams, is ash other than ash of protein.

In the second place, while it has been stated above that the sum of the elements in these compounds, as computed from their percentage composition, should equal the quantities of elements lost, there are slight discrepancies, amounting to but 0.1 or 0.2 of a gram, which are due to the dropping of

TABLE 10.—*Elements and materials katabolized in the body—Metabolism experiment No. 59.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.[1]	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.[1]
1908.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 18–19	11.84	191.57	279.75	2074.15	2247.48	71.04	150.72	89.16	6.94
Dec. 19–20	14.11	190.11	213.36	1537.67	1655.87	84.66	156.61	59.41	8.20
Dec. 20–21	14.82	188.24	206.29	1458.17	1592.35	88.92	183.39	4.22	8.67
Total, 3 days.	40.77	569.92	699.40	5069.99	5495.70	244.62	490.72	152.79	23.81

[1] See pp. 28–29.

supernumerary figures in the computations. The agreement is sufficiently close, however, to demonstrate the mathematical accuracy of the computation of the protein, fat, glycogen, water, and ash katabolized.

Elements and materials katabolized in the body.—As a result of the computations cited above, we have not only the amounts of the chemical elements lost from the body, but also the chemical compounds expressed in terms of water, protein, fat, carbohydrates, and ash. These are shown in table 10 for each day of the experiment. The figures for the first day are also shown in table 9.

By inspection of the figures for the daily amounts it is seen that, save in the case of the carbohydrates, about the same quantities of materials were lost on

[a] In this particular experiment the quantity of ash was calculated, not determined. See p. 28.

each day, suggesting constancy of katabolism. In comparing the results of the three different days, there is an increasing loss of nitrogen, a nearly constant loss of carbon, a rapidly diminishing loss of hydrogen and oxygen, and consequently a corresponding diminution in the water lost. The striking difference, as has been pointed out above, is in the case of carbohydrates, in which the loss of glycogen becomes markedly less each day. But 4.22 grams of glycogen were oxidized in the body on the last day.

Since experiment No. 59 is one of the earliest experiments in the series in which fasting metabolism was studied, it seems undesirable to discuss the peculiar characteristics of the fasting metabolism until opportunity is had to examine all of the available data; consequently, the data for the subsequent experiments will be presented in due course and the main discussion deferred until all the evidence has been considered. It does seem fitting, however, to explain somewhat more fully the use of terms employed in the tables above.

In discussing material katabolized in the body, objection can be raised to the use of the expression "water katabolized in the body," since in the computations of the quantities of material katabolized water is involved only as preformed water. Aside from this preformed water, which leaves the body as such and is considered in the table as "water katabolized in the body," there is other water resulting from the oxidation of the protein, fat, and carbohydrates. The total water eliminated from the body, namely, the sum of the water of urine, respiration and perspiration, and feces, if any, includes not only the water katabolized in the body in the sense in which the expression is used above (i. e., preformed water), but also the water resulting from the katabolism of the protein, fats, and carbohydrates. Certain discrepancies appear when the attempt is made to compare the water katabolized in the body in table 9 with the total water output. There is an excess of water eliminated over the so-called "water katabolized in the body," but if the water of oxidation of the organic hydrogen of protein, fat, and carbohydrates katabolized is deducted from the total water elimination, the discrepancy disappears. Since a portion of the organic hydrogen of the protein katabolized, i. e., the organic hydrogen of the urine, is not oxidized, this amount must be deducted from the organic hydrogen of the protein. A mathematical verification of these points may be made in the following way:

The total water eliminated equals the weight of the water in the urine, 1494.50 grams (see table 9) plus the water of respiration and perspiration, 982.32 grams, or a total of 2476.82 grams. The water katabolized from the body as preformed water is 2247.48 grams. Thus there was an excess of 229.34 grams excreted as the result of oxidized hydrogen of organic matter. During this day there were katabolized 71.04 grams of protein, 150.72 grams of fat, and 89.16 grams of glycogen. These materials contain 4.97, 17.78, and 5.53 grams of organic hydrogen, respectively—a total of 28.28 grams. Deduct-

ing the organic hydrogen of the urine, 2.60 grams, there remains 25.68 grams, the amount of organic hydrogen that was oxidized during the day. From the ratio of hydrogen to water it is computed that there are 229.6 grams of water resulting from this oxidation. Thus the discrepancy apparently existing between the total elimination of water and the water katabolized from the body is explained by the water of oxidation of organic hydrogen.

This computation assumes that all the organic hydrogen of the urine results from the decomposition products of protein. While the numerous tests for albumen and sugar, which were invariably negative, would preclude the possibility of organic hydrogen from these two sources, nevertheless the marked acidosis observed by Brugsch[1] would lead to the inference that organic matter other than that of the disintegration products of protein might well be present in the solids of urine in fasting experiments. With the data at hand, however, no better method of distinguishing between preformed water and water of oxidation of organic hydrogen has as yet been obtained.

TABLE 11.—*Distribution of intake and outgo of water—Metabolism experiment No. 59.*

Date.	Outgo from the body.			Balance of preformed water.			(g)
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total. (a+b)	(d) Preformed (katabolized) water in outgo.	(e) Intake and drink.	(f) Loss of preformed water. (d−e)	Water of oxidation of organic hydrogen. (c−d)
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 18–19......	1494.50	982.32	2476.82	2247.48	1342.50	904.98	229.34
Dec. 19–20......	927.00	951.95	1878.95	1655.87	1360.20	295.67	223.08
Dec. 20–21......	871.20	943.15	1814.35	1592.35	1188.00	404.35	222.00
Total, 3 days..	3292.70	2877.42	6170.12	5495.70	3890.70	1605.00	674.42
Av. per day....	1097.57	959.14	2056.71	1831.90	1296.90	535.00	224.81

Balance of water.—While the figures in table 10 indicate the loss of elements and materials from the body, the income of water has not been taken into consideration in any of the computations thus far, while the oxygen of the income has been duly considered. Hence it is clear that the loss of water from the body as given in column *e* of table 10 is not the net amount lost, since the body received certain amounts of water daily. Thus, on the first day, there were consumed 1342.5 grams of water; on the second day, 1360.2 grams; on the third day, 1188.0 grams. If the amount of drinking-water is taken into consideration, the actual loss of water from the body is much less than appears in table 10. The true loss of preformed water is therefore the

[1] Zeit. f. exper. Path. u. Ther. (1905), 1, p. 419. Cf. also Bönniger and Mohr, Zeit. f. exper. Path. u. Ther. (1906), 3, p. 675.

difference between the loss represented in table 10 and the intake of water as given in table 2; consequently, on the first day, the loss of water from body tissues would be 2247.48 — 1342.50, or 904.98 grams. A similar computation shows the losses of the second and third days to be 295.67 and 404.35 grams, respectively. The data for obtaining these losses are tabulated in table 11.

Aside from the preformed water in the muscles and tissues of the body which was lost during fasting, there remains to be considered the water resulting from the oxidation of the protein, fats, and carbohydrates katabolized, or the water of oxidation of the organic hydrogen contained in these compounds. Since this water was measured together with the rest of the output, it is included in the total amount of water eliminated from the body, namely, column *c*. Deducting the preformed water lost (column *d*), the values for the water of oxidation of the organic hydrogen are obtained. These are recorded in column *g*.

OUTPUT OF HEAT.

Measurements with the respiration calorimeter include the determination of the heat output of the body. As these measurements have a very direct and important bearing upon the measurements of body material katabolized, a careful inspection of the heat data is of interest.

The larger portion of the heat given off from the body is measured by the current of cold water which passes through the heat absorbers inside the respiration chamber. From the differences in temperature of the water as it enters and leaves the chamber, and the mass of water, the heat absorbed can be computed.

Correction for specific heat of water.—The measurement of heat by this method involves the use of a varying standard, i. e., the calorie at the different ranges of temperature through which the water is warmed, and it is accordingly necessary to reduce these observed heat values to the standard calorie, which in all of the work with the respiration calorimeter thus far has been the calorie at 20° C.[a] There are not immaterial differences in the specific heat of water at different temperatures. These specific heats have been computed and placed in tabular form elsewhere.[b]

The method of reducing this heat to terms of C_{20} is shown in table 12. Thus, in column *a* is recorded the heat measured as the product of the mass of water and the differences in temperature. In column *b*, the range of temperature as expressed in degrees centigrade, and in column *c* the specific heat for these ranges of temperature are shown. By multiplying the heat measured by the specific heat of water at the temperatures used, the heat in terms of C_{20} recorded in column *d* can be obtained.

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[a] The calorie used in all measurements discussed in this report is the quantity of heat required to raise 1 kilo of water from 19.5° to 20.5° C.

[b] U. S. Dept. of Agr., Office of Exp. Sta. Bul. 63, p. 56.

While these changes are small, amounting to less than 4 calories for the whole day, and while it may appear that other discrepancies much greater are neglected, nevertheless it is our custom to include this change in an endeavor to secure the greatest possible accuracy with every factor determined by means of this apparatus. An extended discussion of the errors involved in the different determinations is given elsewhere.[19]

Correction for temperature of water and dishes.—In addition to the heat brought away by the water-current, there are minor changes in the amount of heat in the chamber resulting from the introduction of material at a temperature below or above that of the chamber. In fasting experiments these changes are at a minimum and consist chiefly of the introduction of cold

TABLE 12.—*Heat reduced to terms of C_{20}—Metabolism experiment No. 59 (December 18-19, 1903).*

Date and period.	(*a*) Heat measured.	(*b*) Range of temperature.	(*c*) Specific heat.	(*d*) Heat in terms of C_{20}. $(a \times c)$
	Calories.	°C.		*Calories.*
7 a.m. to 10 a.m.	257.3	9–14	1.0022	257.9
10 a.m. 1 p.m.	204.0	9–14	1.0022	204.4
1 p.m. 4 p.m.	199.9	8–14	1.0025	200.4
4 p.m. 7 p.m.	222.6	9–14	1.0022	223.1
7 p.m. 10 p.m.	205.7	9–14	1.0022	206.2
10 p.m. 1 a.m.	131.2	9–15	1.0021	131.5
1 a.m. 4 a.m.	117.1	9–17	1.0018	117.3
4 a.m. 7 a.m.	157.9	8–17	1.0020	158.2
Total for day	1495.7	....	....	1499.0

drinking-water contained in glass bottles. Occasionally the urine or feces may be withdrawn before they reach the temperature of the chamber. In all cases the time at which the material is put in or taken from the chamber, the nature of the material, and the weight and temperature are recorded. The amounts of heat lost or gained by the water-current due to the differences between the temperature of the calorimeter and the water and dishes used on the first day of experiment No. 59 are given in table 13. The specific heat of glass is taken as 0.2. From the specific heat of the material, the weight in grams, and the differences between the temperature of the material and the calorimeter chamber, the quantities of heat absorbed or given off are computed.

In only one instance during this experiment was any material introduced into the respiration calorimeter above the temperature of the chamber. At 4.30 p. m., December 18, four glass urine bottles, weighing 1743 grams, were introduced at a temperature 1° above that of the chamber. All other cor-

[19] Carnegie Institution of Washington Publication No. 42; U. S. Dept. of Agr., Office of Exp. Sta. Bul. 175.

rections were due to cold drinking-water. The sum of the corrections for this day is 22.7 calories, or, in other words, 22.7 calories of heat were required to warm the objects to the temperature of the calorimeter chamber, and hence were not measured in the water-current.

Capacity correction of the calorimeter.—Even with the most skillful physical assistants slight fluctuations in the temperature of the calorimeter are unavoidable, and since the large mass of metal is capable of storing and yielding considerable quantities of heat, the result of these fluctuations must be taken into consideration to determine correctly the total heat elimination for any given period. From a number of tests, which, however, admittedly partake more

TABLE 13.—*Correction applied to the heat measured for temperature of water and dishes—Metabolism experiment No. 59 (December 18-19, 1903).*

Time.	Article.	(a) Specific heat.	(b) Weight.	(c) Temperature.	(d) Temperature of calorimeter.	(e) Difference.	(f) Heat ($a \times b \times e$).	(g) Correction.
			Grams.	°C	°C	°C	*Calories.*	*Calories.*
8h 00m a.m..	Water..	1.0	400	7.6	19.9	12.3	+4.920	
	Glass..	.2	297	7.6	....	....	+ .731	+ 5.7
12h 10m p.m..	Water..	1.0	400	8.5	20.0	11.5	+4.600	
	Glass..	.2	640	8.5	....	....	+1.472	+ 6.1
4h 30m p.m..	Water..	1.0	400	7.8	20.0	12.2	+4.880	
	Glass..	.2	297	7.8	....	....	+ .725	
	Do ..	.2	1743	21.0	20.0	1.0	− .349	+ 5.3
10h 5m p. m..	Water..	1.0	400	7.8	20.0	12.2	+4.880	
	Glass..	.2	297	7.8	....	....	+ .725	+ 5.6
	Total..	....	....	....	....	....	....	+22.7

of the nature of close estimates than of scientific experiments, the hydrothermal equivalent of the calorimeter has been found to be 60 kilos. Consequently, to obtain the capacity correction of the calorimeter, the temperature fluctuations in degrees centigrade are multiplied by 60.

Correction for heat in bedding.—The necessity of correcting the heat measured for the heat in the bedding is based upon the fact that during the period from 10 p. m. to 1 a. m., when the subject retires at night, a considerable quantity of heat is produced which is not liberated into the air of the chamber, but is retained by the bed and bedding until some time after the subject has risen in the morning. From the heat eliminated and other factors it has been computed, though by crude methods, that 30 calories of heat are thus absorbed and liberated by the bedding. Consequently, during the first period in the morning, there is a certain increment of heat measured by the water-

current which was stored in the bedding during the previous night, and hence must be deducted.

TABLE 14.—*Summary of calorimetric measurements and total heat eliminated—Metabolism experiment No. 59.*

Date and period.	(a) Heat measured in terms of C_{20}.	(b) Change in temperature of calorimeter.	(c) Capacity correction of calorimeter. (b × 60)	(d) Correction due to temperature of water and dishes.	(e) Correction for heat in bedding retained (+), liberated (−).	(f) Water vaporized equals total amount in outgoing air plus gain or loss from preceding period.	(g) Heat used in vaporization of water. (f×0.592)	(h) Total heat eliminated. (a+c+d+e+g).
1908. Dec. 18: Preliminary:	*Cals.*	°*C.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Cals.*	*Cals.*
1 a.m. to 4 a.m.	146.07	+0.10	+6.00	....	....	125.61	74.36	226.43
4 a.m. 7 a.m.	140.57	− .10	−6.00	....	....	133.20	78.85	213.42
Total.........	286.64	....	....	....	....	258.81	153.21	439.85
Dec. 18–19:								
7 a.m. to 10 a.m.	257.90	+ .10	+6.00	+ 5.70	−30.00	136.41	80.75	320.35
10 a.m. 1 p.m.	204.40	+ .02	+1.20	+ 6.10	....	130.01	76.97	288.67
1 p.m. 4 p.m.	200.40	+ .01	+ .60	....	....	119.64	70.83	271.83
4 p.m. 7 p.m.	223.10	− .14	−8.40	+ 5.30	....	133.74	79.17	299.17
7 p.m. 10 p.m.	206.20	+ .07	+4.20	+ 5.60	....	114.34	67.69	283.69
10 p.m. 1 a.m.	131.50	− .04	−2.40	....	+30.00	116.87	69.19	228.29
1 a.m. 4 a.m.	117.30	+ .03	+1.80	....	....	115.41	68.32	187.42
4 a.m. 7 a.m.	158.20	+ .05	+3.00	....	....	115.90	68.61	229.81
Total.........	1499.00	+ .10	+6.00	+22.70	....	982.32	581.53	2109.23
Dec. 19–20:								
7 a.m. to 10 a.m.	246.60	− .09	−5.40	+ 5.60	−30.00	124.47	73.69	290.49
10 a.m. 1 p.m.	203.50	− .01	− .60	+ 5.90	....	121.97	72.21	281.01
1 p.m. 4 p.m.	192.80	+ .11	+6.60	....	....	114.98	68.06	267.46
4 p.m. 7 p.m.	212.50	− .08	−4.80	+ 4.80	....	120.91	71.58	284.08
7 p.m. 10 p.m.	222.10	+ .07	+4.20	+ 5.40	....	121.68	72.03	303.73
10 p.m. 1 a.m.	136.20	+ .03	+1.80	....	+30.00	115.15	68.17	236.17
1 a.m. 4 a.m.	134.40	− .13	−7.80	....	....	111.53	66.03	192.63
4 a.m. 7 a.m.	172.50	+ .06	+3.60	....	....	121.26	71.79	247.89
Total.........	1520.60	− .04	−2.40	+21.70	....	951.95	563.56	2103.46
Dec. 20–21:								
7 a.m. to 10 a.m.	248.60	− .04	−2.40	+ 5.60	−30.00	119.60	70.80	292.60
10 a.m. 1 p.m.	194.00	+ .10	+6.00	+ 5.30	....	120.62	71.41	276.71
1 p.m. 4 p.m.	199.80	− .07	−4.20	....	....	119.34	70.65	266.25
4 p.m. 7 p.m.	218.10	+ .03	+1.80	− 0.50	....	114.11	67.55	286.95
7 p.m. 10 p.m.	221.70	− .05	−3.00	+ 4.50	....	119.43	70.70	293.90
10 p.m. 1 a.m.	140.80	− .04	−2.40	....	+30.00	111.25	65.86	234.26
1 a.m. 4 a.m.	161.30	+ .09	+5.40	....	....	121.98	72.21	238.91
4 a.m. 7 a.m.	153.20	− .04	−2.40	....	....	116.82	69.16	219 96
Total.........	1537.50	− .02	−1.20	+14.90	....	943.15	558.34	2109.54

Consequently, during the first period in the morning, the correction is negative, since the heat is in excess of that normally produced, while during

the period from 10 p. m. to 1 a. m. the correction is positive. It is important to note that no matter what error affects this correction, it is a compensating one and hence it does not affect the measurement of the heat elimination for the 24 hours. It affects only the two periods to which the corrections are applied.

Correction for the heat of vaporization of water.—A very considerable proportion of the total heat given off from the body, especially during rest, is used for the vaporization of water from the lungs and skin. The amount of water thus vaporized equals the total amount in the outgoing air plus the gain or loss of water vapor in the residual air from the preceding period. For the want of a more accurate factor for the heat of vaporization of 1 gram of water at the temperature of the calorimeter we have used the factor 0.592, based on Regnault's work.

Summary of calorimetric measurements.—The various corrections mentioned above to be applied to the heat measured by the calorimeter are given in table 14, the total corrected heat eliminated being recorded in column *h*.

TOTAL HEAT PRODUCTION.

The simple measurement of heat lost by the body is not sufficient for the proper interpretation of the processes of metabolism. Since metabolism and heat production rather than heat elimination go hand in hand, it is of vital importance to distinguish between heat production and heat elimination; and for accurate measurements of heat production, knowledge of the fluctuations in the store of heat in the body is absolutely essential.

Changes in the residual heat in the body due to variation in body weight and temperature.—The body of the subject may be said to be a large reservoir for heat and the quantity of heat thus stored in the body varies with every period of the day. Even with constant body temperature there are noticeable fluctuations in body-weight which involve considerable changes in the amount of heat actually existing in the body. Similarly, differences in body temperature cause fluctuations in the storage of heat. For example, if a subject weighs 60 kilos and there is a rise of temperature of 1° C., this is practically equivalent to the storage of 50 calories, since the specific heat of the body is not far from 0.83. A corresponding fall of temperature is followed by a corresponding loss from the store of heat. But even though the temperature be constant, if the body loses 500 grams in weight, obviously 500 grams of material have been cooled from the temperature of the body, 37° C., to the temperature of the chamber, 20° C., and thus 7.1 calories of heat have been given up which were not actually produced during the period.

If the calorimeter chamber were provided with a weighing arrangement whereby body-weights could be taken at the end of each experimental period, part of the data for these corrections could be readily secured. Unfortunately,

as yet no simple arrangement seems to be possible for securing the body-weight of the subject at the end of each period without the extraneous muscular effort of adjusting the furniture in the chamber and suspending the weighing chair on the special scale provided for the purpose. Therefore the weighings are usually made but once each day. From the weights so found, the changes in body-weight from period to period were computed. The details of such computations are shown for the first day of this experiment in table 15.

The income consists of oxygen and water consumed, and the outgo, of water of respiration and perspiration, carbon dioxide, and urine. During the period

TABLE 15.—*Change of body-weight during different periods of the day—Metabolism experiment No. 59 (December 18-19, 1903).*

Time.	Income.		Outgo.			(f) Balance (a+b) −(c+d+e).	(g) Body-weight.
	(a) Oxygen consumed.	(b) Water consumed.	(c) Water of respiration.[1]	(d) Carbon dioxide eliminated.	(e) Urine.		
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Kilos.*
7 a.m.	....	....	....	....	....	....	67.796
7 to 10 a.m.	95.33	400.00	136.41	101.76	455.80	−198.64	....
10 a.m.	....	....	....	....	....	....	67.597
10 a.m. to 1 p.m.	79.66	400.00	130.01	88.82	190.20	+ 70.63	....
1 p.m.	....	....	....	....	....	....	67.668
1 to 4 p.m.	74.64	....	119.64	88.29	252.20	−385.49	....
4 p.m.	....	....	....	....	....	....	67.282
4 to 7 p.m.	96.60	400.00	133.74	98.58	528.70	−264.42	....
7 p.m.	....	....	....	....	....	....	67.018
7 to 10 p.m.	85.64	....	114.34	81.70	129.30	−239.70	....
10 p.m.	....	....	....	....	....	....	66.778
10 p.m. to 1 a.m.	69.22	142.50	116.87	74.12	203.70	−182.97	....
1 a.m.	....	....	....	....	....	....	66.595
1 to 4 a.m.	63.35	....	115.41	65.29	....	−117.35	....
4 a.m.	....	....	....	....	....	....	66.478
4 to 7 a.m.	64.98	....	115.90	71.99	....	−122.91	....
7 a.m.	....	....	....	....	....	....	66.355

[1] Includes also water of perspiration.

from 7 to 10 a. m. there was a total loss from the body of 198.64 grams over and above the income of oxygen and water. Thus the body-weight at 10 o'clock was less by 199 grams than it was at 7 a. m. During the next period the income was slightly larger than the output and therefore the body-weight was slightly increased. The computations for the remaining periods of the day, with the final corrected body-weight, appear in the table.

Unfortunately, in this particular experiment the special scale for weighing the man had not been installed and the body-weights were very defective, but from later observations on this same subject it is assumed that when naked he weighed 67.796 kilos. That this figure is very nearly correct seems fairly

certain from a comparison of these data with weights taken by the subject, the weight of clothes being taken into consideration. The figure above was therefore taken as a basis.

TABLE 16.—*Determinations of body temperature and body-weight, with corresponding heat corrections—Metabolism experiment No. 59.*

Date and time.	Body temperature.		Body-weight.		
	(*a*) By rectal thermometer.	(*b*) Rise (+) or fall (−) from preceding period.	(*c*) Calculated.	(*d*) Gain (+) or loss (−) from preceding period.	(*e*) Correction for change of body temperature and weight.
1908.	*°C.*	*°C.*	*Kilos.*	*Grams.*	*Calories.*
Dec. 18, 7 a.m.....	36.72	....	[1]67.796	....	....
10 a.m.....	37.00	+0.28	67.597	− 199	+ 12.92
1 p.m.....	36.75	− .25	67.668	+ 71	+ 13.04
4 p.m.....	36.84	+ .09	67.282	− 386	− .34
7 p.m.....	36.94	+ .10	67.018	− 264	+ 1.86
10 p.m.....	36.55	− .39	66.778	− 240	− 24.96
Dec. 19, 1 a.m.....	36.35	− .20	66.595	− 183	− 13.58
4 a.m.....	36.45	+ .10	66.478	− 117	+ 3.94
7 a.m.....	36.56	+ .11	66.355	− 123	+ 4.38
Total for day...	.....	− .16	......	−1441	− 28.82
Dec. 19, 7 a.m.....	36.56	....	66.355	....	....
10 a.m.....	36.96	+ .40	66.401	+ 46	+ 22.68
1 p.m.....	36.83	− .13	66.579	+ 178	− 4.72
4 p.m.....	36.85	+ .02	66.352	− 227	− 2.06
7 p.m.....	36.73	− .12	66.499	+ 147	− 4.56
10 p.m.....	36.61	− .12	66.370	− 129	− 8.40
Dec. 20, 1 a.m.....	36.45	− .16	66.155	− 215	− 11.72
4 a.m.....	36.61	+ .16	66.041	− 114	+ 7.20
7 a.m.....	36.73	+ .12	65.917	− 124	+ 4.86
Total for day...	.....	+ .17	......	− 438	+ 3.28
Dec. 20, 7 a.m.....	36.73	....	65.917	....	....
10 a.m.....	36.89	+ .16	65.798	− 119	+ 7.08
1 p.m.....	36.99	+ .10	65.953	+ 155	+ 7.62
4 p.m.....	37.00	+ .01	65.697	− 256	− 3.04
7 p.m.....	37.01	+ .01	65.388	− 309	− 3.84
10 p.m.....	36.58	− .43	65.553	+ 165	− 21.06
Dec. 21, 1 a.m.....	36.41	− .17	65.339	− 214	− 12.16
4 a.m.....	36.45	+ .04	65.221	− 118	+ .58
7 a.m.....	36.80	+ .35	65.093	− 128	+ 17.14
Total for day...	.....	+ .07	......	− 824	− 7.68

[1] The weight given for 7 a. m. arbitrarily assumed.

In addition to the fluctuations in body-weight, it is necessary in order to get the true heat produced, to know also the changes in body temperature. These latter were taken with the electrical rectal thermometer, which has been described in detail.[11] While reserving the list of thermometric observations for

[11] Benedict & Snell, Archiv f. d. ges. Physiol. (1901), 88, pp. 492-500; Carnegie Institution of Washington Publication No. 42, p. 156.

discussion elsewhere, it will suffice for the particular purpose in view to give the body temperature determinations for the end of each period. These are recorded in column *a* of table 16. The differences from period to period are recorded in the second column. The data recording the body-weight are given in columns *c* and *d*, while the final column gives the differences, due to changes in body-weight and temperature, in the amount of heat stored in the body.

TABLE 17.—*Total heat production—Metabolism experiment No. 59.*

Date and period.			(*a*) Total heat eliminated.	(*b*) Correction due to change of body temperature and weight.	(*c*) Total heat production. ($a + b$)
1908.			*Calories.*	*Calories.*	*Calories.*
Dec. 18–19,	7 a.m. to	10 a.m.	320.35	+12.92	333.27
	10 a.m.	1 p.m.	288.67	−13.04	275.63
	1 p.m.	4 p.m.	271.83	− .34	271.49
	4 p.m.	7 p.m.	299.17	+ 1.86	301.03
	7 p.m.	10 p.m.	283.69	−24.96	258.73
	10 p.m.	1 a.m.	228.29	−13.58	214.71
	1 a.m.	4 a.m.	187.42	+ 3.94	191.36
	5 a.m.	7 a.m.	229.81	+ 4.38	234.19
	Total		2109.23	−28.82	2080.41
Dec. 19–20,	7 a.m. to	10 a.m.	290.49	+22.68	313.17
	10 a.m.	1 p.m.	281.01	− 4.72	276.29
	1 p.m.	4 p.m.	267.46	− 2.06	265.40
	4 p.m.	7 p.m.	284.08	− 4.56	279.52
	7 p.m.	10 p.m.	303.73	− 8.40	295.33
	10 p.m.	1 a.m.	236.17	−11.72	224.45
	1 a.m.	4 a.m.	192.63	+ 7.20	199.83
	4 a.m.	7 a.m.	247.89	+ 4.86	252.75
	Total		2103.46	+ 3.28	2106.74
Dec. 20–21,	7 a.m. to	10 a.m.	292.60	+ 7.08	299.68
	10 a.m.	1 p.m.	276.71	+ 7.62	284.33
	1 p.m.	4 p.m.	266.25	− 3.04	263.21
	4 p.m.	7 p.m.	286.95	− 3.84	283.11
	7 p.m.	10 p.m.	293.90	−21.06	272.84
	10 p.m.	1 a.m.	234.26	−12.16	222.10
	1 a.m.	4 a.m.	238.91	+ .58	239.49
	4 a.m.	7 a.m.	219.96	+17.14	237.10
	Total		2109.54	− 7.68	2101.86

In order to show the method by which the change in the amount of heat stored in the body of the subject (column *e*) is found, a concrete example is here taken. At 7 a. m., December 18, the subject weighed 67.796 kilos, the body temperature was 36.72°, and the calorimeter temperature was 20°. If his body had cooled down to the calorimeter temperature immediately, the quantity of heat which would have been liberated would be 67.796 × 0.83 (the specific heat of body material) × 16.72 (difference between the temperature of the

body and the calorimeter) = 940.88 calories. Similarly, at 10 a. m. the body weight was 67.597 kilos, and the difference between body temperature and calorimeter temperature was 17°. The formula would then be $67.597 \times 0.83 \times 17.0 = 953.80$. The difference between the amounts of heat in the body reduced to 20° at 7 a. m. and 10 a. m. is $953.80 - 940.88 = 12.92$ calories. There were, therefore, 12.92 calories of heat stored in the body more than were present at 7 a. m., and consequently, since this quantity of stored heat was derived from the heat produced during this period, it should be added to the heat eliminated to give the heat production. The results for all the different periods are recorded in column *e*.

Relation of heat production to heat elimination.—The total heat production is the heat eliminated corrected for changes in the amount of heat residual in the body. The corrections for the heat elimination have previously been

TABLE 18.—*Amounts of body protein, fat, and glycogen katabolized and energy of each*[1]*—Metabolism experiment No. 59.*

Date.	Protein.		Fat.		Glycogen.		(g) Total energy.
	(a) Amount.	(b) Energy.	(c) Amount.	(d) Energy.	(e) Amount.	(f) Energy.	(b+d+f)
1908.	*Grams.*	*Calories.*	*Grams.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Dec. 18–19......	71.04	401	150.72	1438	89.16	374	2213
Dec. 19–20......	84.66	478	156.61	1494	59.41	249	2221
Dec. 20–21	88.92	502	183.39	1750	4.22	18	2270

[1] Factors for heat of combustion per gram of protein, 5.65 calories; fat, 9.54 calories; glycogen, 4.19 calories.

considered and are tabulated in columns *c* to *g* of table 14. The corrections for the changes in the amounts of heat residual in the body as found in table 16 are applied to the corrected heat elimination and thus the total heat production is obtained. These results are shown in table 17.

Energy of body material lost.—The quantities of protein, fat, and carbohydrates katabolized in the body have been computed from the chemical analyses and the formulæ given on page 38. The energy of these compounds may be computed from the weights katabolized and the heats of combustion of body protein, fat, and carbohydrates. The heat of combustion of fat-free muscular tissue from which the nitrogenous extractives have not been removed is not far from 5.65 calories per gram. A large number of determinations of the heat of combustion of human fat made in this laboratory[13] averaged 9.54 calories per gram. The heat of combustion of glycogen has frequently been determined as 4.19 calories per gram. The computation, therefore, of the energy resulting from the katabolism of any one of these three different compounds in the

[13] Benedict & Osterberg, Amer. Journ. Physiol. (1900), 4, pp. 69-76.

body may be made by multiplying its amount in grams by its heat of combustion. The results are stated in table 18. The total energy which would result from the katabolism of the varying amounts of the protein, fat, and glycogen is given in the last column.

It should be here noted that these figures represent the total potential energy of the different materials and not the actual energy liberated in the body, for while in the katabolism of fat and carbohydrates the total heat of oxidation is liberated, in the katabolism of protein a certain moiety is eliminated as the potential energy of urine.

BALANCE OF ENERGY.

As the total heat produced is derived from the katabolism of body protein, fat, and carbohydrates, there should be an exact balance between the computed

TABLE 19.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 59.*

Date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater than output.	
	From body protein.			(d) From body fat.	(e) From body glycogen.	(f) Total. (c+d+e)		(h) Amt. (f−g)	(i) Proportion. (h ÷ g)
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a−b).						
1903.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Per ct.
Dec. 18–19....	401	91	310	1438	374	2122	2080	42	2.0
Dec. 19–20....	478	106	372	1494	249	2115	2107	8	0.4
Dec. 20–21....	502	111	391	1750	18	2159	2102	57	2.7
Total, 3 days.	1381	308	1073	4682	641	6396	6289	107	....
Av. per day..	460	103	357	1561	214	2132	2096	36	1.7

total energy of the materials oxidized in the body and the total heat produced. That such a balance exists, though it is not a perfect one, appears from a consideration of table 19. Since, however, not all the potential energy of the protein is actually liberated in its katabolism, the net energy from the body protein is derived by deducting the potential energy of the urine from the energy of the protein katabolized. This computation is made in the first three columns of the table. The energy of body fat and glycogen katabolized are identical with the amounts shown in table 18. The total energy derived from the different sources, therefore, is the sum of the net energy of the protein, the heat of combustion of the body fat, and the heat of combustion of the body glycogen. This total is recorded in column *f*. The total heat production shown in table 17 is recorded in column *g* above. Theoretically at least, we should expect that the total heat production would correspond to the total energy derived from the

different sources. The difference between these two quantities is shown in column *h* and the percentage discrepancy is given in the last column.

The difficulties of striking an accurate balance of this kind for an experiment of 24 hours' duration are obvious, since there are a number of physiological errors involved which preclude extremely accurate work. On the other hand, if the experimental period be made to cover several days, the physiological errors may and doubtless do in a large measure compensate. From the average of the three days of this experiment, it appears that the average heat production as measured by the calorimeter with corrections is 36 calories less than the estimated energy derived from the different sources or an error of + 1.7 per cent. Further discussion of the magnitude of this error and its relation to other experiments is deferred.

In computing the percentage discrepancy between the total heat production and the estimated energy of material oxidized in the body the former is used as the standard of measurement and the error assumed to be due to the estimates of the energy of material oxidized in the body. Although the direct measurement of oxygen furnishes data for a more exact estimation of the products of katabolism than has heretofore been obtained, it is believed that at present the errors in the assumption of the energy of material katabolized in the body are greater than the errors in the determination of the heat production and hence the latter factor is used as the standard for comparison. It is to be noted, however, that not only in this, but in the whole series of experiments here reported, the agreement between the total heat production and the estimate of the energy of body material actually oxidized is, on the whole, very satisfactory.

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

Since heat is the result of the oxidative processes in the body it is natural to suppose that there would be some simple relations existing between the quantities of oxygen absorbed, the quantities of carbon dioxide eliminated, and the heat produced. The data on this point are given in table 20.

In earlier experiments, where the amounts of oxygen and carbon dioxide were determined, the heat was not directly determined, but the ratio of the respiratory gases has been of great value in estimating the heat production.

Oxygen thermal quotient.—The ratio between the amount of oxygen consumed and the amount of heat produced may be termed the oxygen thermal quotient, and this ratio can be expressed as the number of grams of oxygen that is absorbed to produce 100 calories of heat.

The ratios between the oxygen, carbon dioxide, and heat are of interest not only for the whole day, but also for the shorter periods, and hence in column *c* the oxygen thermal quotient for each 3-hour period has been recorded.

Carbon dioxide thermal quotient.—The ratio between the carbon dioxide eliminated and the heat produced is also of value in interpreting the nature of the metabolism. This ratio, which is expressed in terms of the number of

TABLE 20.—*Oxygen and carbon dioxide thermal quotients, and respiratory quotients—Metabolism experiment No. 59.*

Date and period.	(*a*) Total heat production.	(*b*) Oxygen consumed.	(*c*) Oxygen thermal quotient (100 *b*÷*a*).	(*d*) Carbon dioxide eliminated.	(*e*) Carbon dioxide thermal quotient (100 *d*÷*a*).	(*f*) Volume of carbon dioxide eliminated (*d* × 0.5091).	(*g*) Volume of oxygen consumed (*b* × 0.7).	(*h*) Respiratory quotient (*f*÷*g*).
1908.								
Dec. 18:								
Preliminary:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1 a.m. to 4 a.m.	....	58.9	....	69.7	....	35.5	41.2	0.86
4 a.m. 7 a.m.	....	70.4	....	79.0	....	40.2	49.3	.82
Dec. 18–19:								
7 a.m. to 10 a.m.	333.3	95.3	28.6	101.8	30.5	51.8	66.7	.78
10 a.m. 1 p.m.	275.6	79.7	28.9	88.8	32.2	45.2	55.8	.81
1 p.m. 4 p.m.	271.5	74.6	27.5	88.3	32.5	45.0	52.3	.86
4 p.m. 7 p.m.	301.0	96.6	32.1	98.6	32.8	50.2	67.6	.74
7 p.m. 10 p.m.	258.7	85.6	33.1	81.7	31.6	41.6	59.9	.69
10 p.m. 1 a.m.	214.7	69.2	32.2	74.1	34.5	37.7	48.5	.78
1 a.m. 4 a.m.	191.4	63.4	33.1	65.3	34.1	33.2	44.3	.75
4 a.m. 7 a.m.	234.2	65.0	27.8	72.0	30.7	36.7	45.5	.81
Total.........	2080.4	629.4	30.3	670.6	32.2	341.4	440.6	.78
Dec. 19–20:								
7 a.m. to 10 a.m.	313.2	102.5	32.7	95.0	30.3	48.4	71.8	.67
10 a.m. 1 p.m.	276.3	72.5	26.3	85.9	31.1	43.8	50.8	.86
1 p.m. 4 p.m.	265.4	77.7	29.3	83.4	31.4	42.4	54.4	.78
4 p.m. 7 p.m.	279.5	80.2	28.7	88.5	31.6	45.0	56.1	.80
7 p.m. 10 p.m.	295.3	89.6	30.3	90.7	30.7	46.2	62.7	.74
10 p.m. 1 a.m.	224.5	68.3	30.4	72.1	32.1	36.7	47.8	.77
1 a.m. 4 a.m.	199.8	64.1	32.1	65.9	33.0	33.5	44.8	.75
4 a.m. 7 a.m.	252.7	74.4	29.4	77.5	30.7	39.5	52.1	.76
Total.........	2106.7	629.3	29.9	659.0	31.3	335.5	440.5	.76
Dec. 20–21:								
7 a.m. to 10 a.m.	299.7	98.0	32.7	95.9	32.0	48.8	68.6	.71
10 a.m. 1 p.m.	284.3	82.7	29.1	83.6	29.4	42.5	57.9	.73
1 p.m. 4 p.m.	263.2	96.0	36.5	85.7	32.6	43.7	67.2	.65
4 p.m. 7 p.m.	283.1	79.8	28.2	84.2	29.7	42.9	55.9	.77
7 p.m. 10 p.m.	272.9	84.5	31.0	86.4	31.7	44.0	59.2	.74
10 p.m. 1 a.m.	222.1	71.4	32.2	74.1	33.4	37.7	50.0	.76
1 a.m. 4 a.m.	239.5	77.6	32.4	73.3	30.6	37.3	54.3	.69
4 a.m. 7 a.m.	237.1	56.1	23.6	67.1	28.3	34.2	39.2	.87
Total.........	2101.9	646.1	30.7	650.3	30.9	331.1	452.3	.73

grams of carbon dioxide accompanying the production of 100 calories of heat, has been given in column *e*. A particular discussion of this, as well as other quotients, will be found beyond.

Respiratory quotient.—The relationship first recognized and studied was that existing between the carbon dioxide eliminated and the oxygen consumed—

the so-called respiratory quotient. This respiratory quotient is based upon relations of the volume of these two gases, and therefore the volumes of carbon dioxide eliminated and oxygen consumed have been recorded in columns *f* and *g*. These are readily obtained from the weights of carbon dioxide and oxygen by means of the factors given in the column headings. The respiratory quotient is the ratio between them, as expressed in the last column. Numerous incidental errors affect at times very noticeably the value of the respiratory quotient for the different periods. These errors have been discussed in detail elsewhere.[13] For the 24 hours, however, the respiratory quotients are probably not far from correct. These values range from 0.78 on the first day of the experiment to 0.73 on the last day.

[13] Carnegie Institution of Washington Publication No. 42; U. S. Dept. Agric., Office of Exp. Sta. Bul. 175.

METABOLISM EXPERIMENT NO. 68.

This experiment, which lasted two days, followed immediately a series of experiments covering 11 consecutive days, made with the same subject inside the respiration calorimeter. The previous series has been reported elsewhere.[14]

While in the majority of the fasting experiments here reported, accurate knowledge of the metabolic activity before the fast was not available, in this instance the metabolism for several days before the fasting period was accurately measured.

Three series of experiments preceded the fasting period. The first was a 3-day experiment, during which the subject was engaged in hard muscular labor riding a bicycle ergometer[15] for 6 hours each day and received a diet furnishing about 100 grams of protein and 4630 calories of energy per day. The diet during this period consisted in large part of carbohydrates. The second was also a work experiment of 3 days' duration, during which a diet containing approximately the same amount of nitrogen as the preceding, but with slightly increased energy, averaging not far from 4750 calories per day, was given. During this experiment the diet consisted in large part of fat, chiefly in the form of cream. The third series consisted of 4 experiments, beginning with a 1-day experiment, during which a diet containing 19.11 grams of nitrogen and 5393 calories of energy, chiefly in the form of cream, was provided. On this day the subject did an unusual amount of muscular work on the bicycle ergometer, riding until far into the night. The severe work day was followed by a rest experiment of 1 day, during which the subject spent the most of his time in bed, recuperating from the excessive work of the preceding day. The diet contained 15.4 grams of nitrogen and 2369 calories of energy. During the next experiment, which was also of 1 day's duration, the subject prepared the ergometer and removed clothing for riding, but immediately dressed himself and did not ride, the purpose being to determine the energy required for the extraneous muscular work other than that involved in riding the ergometer. The diet for this day furnished 14.11 grams of nitrogen and 2062 calories of energy. On each of the two following days the subject rode the bicycle ergometer for 6 hours. The riding corresponded to the free leg-motion of coasting, since no resistance was applied to cause the subject to do work. During these two days, which are of more especial interest in considering the subsequent fasting period, the diet supplied about 11 grams of nitrogen

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[14] U. S. Dept. Agriculture, Office of Exp. Sta. Bul. 175.

[15] The bicycle ergometer is an apparatus for measuring accurately the external muscular work of riding. It is practically a stationary bicycle. For a description, see Carnegie Institution of Washington Publication No. 42, p. 164.

and 2100 calories of energy. The diet was extremely simple, consisting of crackers, sugar, and milk. The details of the preceding experiments are given in another publication.[16]

The subject had undoubtedly become thoroughly accustomed to life inside the respiration calorimeter and to the daily routine during the previous 11 days, consequently the fasting experiment was made under conditions ideal for obtaining minimum muscular activity. No prescribed program was insisted upon. He was provided with reading and writing materials and every care was taken to make him as comfortable as possible.

The clothing worn by the subject was essentially the same as that worn by all others, namely, union suit, stockings, trousers, sweater or coat as desired, and slippers or rubber-soled shoes.

A. L. L. was a student in the university. In temperament he was rather phlegmatic and slow in speech and movement. His physical strength was above the ordinary. The records of his body measurements are given below. From the date of the anthropometric records, it will be seen that these measurements were taken six months prior to the date of the experiment.

Measurements of A. L. L.—Date, Oct. 24, 1903. Age 22 years, 8 months.

Weight	kilograms..	73.3
Height	centimeters..	166.3
Length of—		
Sternum	do....	138.9
Navel	do....	101
Pubis	do....	83.4
Sitting	do....	90.2
Knees	do....	44.1
Shoulders, elbow	do....	37.5
Elbow to tip	do....	45.2
Arm reach	do....	175.9
Right foot	do....	26.8
Left foot	do....	26.7
Girth of—		
Head	do....	57.1
Neck	do....	37
Chest—		
Depressed	do....	93.5
Inflated	do....	102
Normal	do....	99.8
At 9th rib, full	do....	94.5
At 9th rib, depressed	do....	93.4
Waist	do....	81.3
Hips	do....	97.7
Right biceps	do....	33.6
Left biceps	do....	33.5
Right arm	do....	30.2
Girth of—		
Left arm	centimeters..	30.5
Right elbow	do....	24.8
Left elbow	do....	24.9
Right forearm	do....	30
Left forearm	do....	29.5
Right wrist	do....	17.3
Left wrist	do....	17.5
Right thigh	do....	56.5
Left thigh	do....	56
Right knee	do....	37.8
Left knee	do....	38.2
Right calf	do....	36.9
Left calf	do....	36.7
Right instep	do....	25.9
Left instep	do....	25.6
Breadth of—		
Head	do....	15.1
Neck	do....	11.4
Shoulders	do....	43.2
Chest	do....	28.8
Waist	do....	27.3
Hips	do....	33.9
Depth of—		
Chest	do....	21
Abdomen	do....	20.4

[16] U. S. Dept. Agriculture, Office of Exp. Sta. Bul. 175.

The following notes from the diary of the subject are of especial interest as an index of his physical state:

Notes from diary.

April 27, 1904. Took a lampblack capsule this morning and drank a little water. The day passed quite quickly because of interesting reading matter. Felt a little craving for food in the evening and some weakness. Retired and slept well, waking a little before 7 a. m.

April 28, 1904. Felt a definite craving for food about breakfast time, but it soon passed away. Felt weak and lifeless; belched considerable wind. About bedtime I felt unusually weak. This was particularly noticeable because I had not been moving around for some time. After lying down I didn't feel very hungry and soon went to sleep. Was wakeful and restless during the latter part of the night.

Routine.—Since it interferes materially with fasting subjects to insist upon a prescribed routine, the subject of this experiment was only cautioned to minimize so far as possible the muscular movements. His experience of the 11 preceding days aided materially in securing uniform experimental conditions during the fasting period. The experimental day began as usual at 7 o'clock in the morning and, since the last meal was taken at 6 o'clock the night before, there had been a fast of 13 hours before the experiment proper began.

Body movements.—The usual movements incidental to drinking water, taking pulse, caring for excreta, opening and closing the food aperture, etc., were unavoidable. Although the subject attempted to secure uniform bodily activity on the two days of the experiment, an inspection of the record of body movements will show that this was extremely difficult. The major body movements obtained by the physical observer and reported in the diary of the subject are given herewith.

Movements of subject.—Duration, two days, from Apr. 27, 7 a. m., to Apr. 29, 7 a. m., 1904.

	April 27.
A. M.	
$7^{h}\,00^{m}$	**rise.**
7 02	**weigh self.**
7 04	**weigh clothes.**
7 06	**weigh absorbers.**
7 10	**urinate.**
7 12	**take temperature.**
7 20	**dress.**
7 24	**sit.**
7 28	**food aperture.**
7 32	**sit.**
7 40	**food aperture.**
8 16	**move about, prepare ergometer,[1] undress.[2]**
8 18	**mount ergometer.**
8 20	**dismount, dress.**
8 30	**sit.**
A. M.	
$8^{h}\,50^{m}$	**telephone.**
9 16	**telephone.**
9 54	**telephone.**
10 02	**food aperture.**
10 16	**telephone.**
10 20	**food aperture.**
10 24	**undress, prepare ergometer.**
10 28	**mount ergometer.**
10 30	**dismount, dress, sit.**
11 48	**telephone.**
P. M.	
$12^{h}\,02^{m}$	**food aperture.**
12 06	**telephone.**
1 00	**urinate.**
3 00	**read.**
3 30	**food aperture.**
P. M.	
$3^{h}\,32^{m}$	**telephone.**
3 56	**telephone.**
4 00	**telephone, food aperture, undress, take temperature.**
4 04	**prepare ergometer, mount and dismount, dress, sit.**
4 20	**read.**
5 12	**telephone.**
5 14	**read.**
5 36	**undress.**
5 42	**dress.**
5 46	**sit, read.**
6 06	**telephone.**
6 08	**food aperture.**
6 10	**sit, read.**
7 02	**food aperture.**

[1] Places the bicycle ergometer in the position in which it is usually ridden.
[2] Record of "undress" during the day indicate that trousers and sweater were removed.

Movements of subject.—Continued.

April 27 (cont.)

P. M.
$7^{h}\,03^{m}$ urinate.
7 04 telephone.
7 06 food aperture.
7 08 take temperature.
7 10 food aperture.
7 12 read.
7 32 telephone.
7 44 read.
10 00 take temperature.
10 52 open bed, undress.
10 56 urinate.
11 00 retire.

April 28.

A. M.
$7^{h}\,00^{m}$ rise.
7 04 weigh self.
7 06 weigh clothes.
7 08 weigh absorbers.
7 10 urinate.
7 14 take temperature.
7 16 sit.
7 20 rise, dress.
7 22 read.
7 26 food aperture.
7 32 sit, read.

A. M.
$7^{h}\,44^{m}$ telephone.
7 54 food aperture.
8 20 move about, undress, prepare ergometer.
8 24 mount.
8 30 dismount, dress.
8 36 sit, read.
10 06 take temperature, telephone.
10 08 food aperture.
10 10 sit, read.
10 16 food aperture.
10 24 prepare ergometer, mount.
10 28 dismount, dress.
10 30 sit, read.
10 36 telephone.
11 10 telephone.

P. M.
$1^{h}\,02^{m}$ urinate.
1 04 food aperture, take temperature.
1 10 sit, read.
1 44 collect drip.[1]
1 50 undress, prepare ergometer.

P. M.
$1^{h}\,52^{m}$ mount.
1 54 dismount, dress.
1 56 sit, read.
3 32 food aperture.
4 00 rise, undress, take temperature.
4 04 food aperture.
4 06 prepare ergometer, mount.
4 08 dismount, dress, sit.
4 10 read.
4 32 telephone.
5 28 rise, undress.
5 30 dress, read.
6 02 rise, food aperture.
6 06 telephone.
6 28 food aperture.
7 00 take temperature.
7 02 urinate.
7 48 rise.
7 50 sit, read.
8 02 read.
10 04 take temperature.
10 08 read.
10 52 collect drip.
11 00 retire.

[1] The water which has accumulated in the drip cans is put into a bottle and passed out through the food aperture.

TABLE 21.—*Record of water consumed—Metabolism experiment No. 68.*

Date.	Period during which water was consumed.			Total for day.
	7 to 10 a. m.	10 a. m. to 1 p. m.	1 to 4 p. m.	
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27–28.....	149.2	119.2	....	268.4
Apr. 28–29.....	330.2	....	286.0	616.2

Drinking-water.—Water for drinking purposes was furnished ad libitum. In order to compute the heat production, the quantity of water consumed during each period of the day (when the record of body movements indicated that water was drunk) was estimated by methods similar to those followed in experiment No. 59. Data for making this apportionment were rather more complete in this experiment than in the previous one. All water was cooled and its temperature taken before it was received by the subject. This is true also of all the experiments following. The amounts obtained by means of these estimates are recorded in table 21.

From table 21 it appears that the quantity of water drunk on the second day of the experiment was much larger than that consumed on the first day; in

fact more than twice as large. Furthermore, all the water was consumed before 4 p. m., which was unusual in these experiments. The quantity of water consumed by A. L. L. was considerably less than that drunk by the subject of experiment No. 59.

URINE.

In this experiment the urine was collected in four periods, from 7 a. m. to 1 p. m., 1 to 7 p. m., 7 to 11 p. m., and 11 p. m. to 7 a. m. This was done in the hope that the analysis of the urine for different periods would throw some light upon the rate of elimination of different ingredients in the urine; for while

TABLE 22.—*Determinations in urine per period and per day—Metabolism experiment No. 68.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a ÷ b).	(d) Reaction.	(e) Nitrogen.
1904.		*Grams.*		c.c.		*Grams.*
Apr. 27-28.	7 a.m. to 1 p.m.	267.5	1.0190	262	Faintly acid..	2.89
	1 p.m. 7 p.m.	264.6	1.0220	259	Slightly acid..	3.31
	7 p.m. 11 p.m.	172.1	1.0215	168	......do......	2.08
	11 p.m. 7 a.m.	297.5	1.0230	290	Acid.........	3.98
	Total	1001.7	....	979	....	12.26
	Total by composite........	1001.7	1.0230	979	....do........	12.32
Apr. 28-29.	7 a.m. to 1 p.m.	221.9	1.0225	217	Acid.........	3.08
	1 p.m. 7 p.m.	223.1	1.0260	217	....do........	3.47
	7 p.m. 11 p.m. } 11 p.m. 7 a.m. }	398.8	1.0270	388	....do........	6.48
	Total..........	843.8	....	822	....	13.03
	Total by composite........	843.8	1.0265	822	Acid.........	13.05
	Total for 2 days.	1845.5	....	1801	....	25.29
	Total by composite for 2 days.	1845.5	1.0255	1801	Acid.........	25.04

the collections were made more frequently in experiment No. 59, with the increased demands upon the time of the assistants, the analysis of urine for short periods had been impossible. The amounts of urine and the specific gravity, volume, reaction, and nitrogen, determined not only by periods but also in the composite sample, are given in table 22.

In addition to the data given in table 22, there were determined on the daily composite samples the heat of combustion and on the composite for the two days the heat of combustion, the water-free material, the carbon, the hydrogen of organic matter, and the ash. The heat of combustion per gram for the urine for April 27-28 was 0.092 calorie. For April 28-29 it was 0.117 calorie. The 2-day composite sample gave 94.94 per cent of water, 1.09 per cent of carbon, 0.25 per cent of organic hydrogen, and 1.22 per cent of ash.

Weight and composition of urine.—The total weights of material excreted in the urine are given in table 23. These include the total weight of urine, the weight of water, solids, ash, organic matter, nitrogen, carbon, hydrogen in organic matter, and oxygen in organic matter. The heat of combustion is also given.

As in experiment No. 59, the determinations of carbon and organic hydrogen were made only on the 2-day composite, and hence it was necessary to apportion the total amounts of carbon and organic hydrogen eliminated according to the amount of nitrogen eliminated on the two days. In apportioning the amounts of water and ash, which were also determined only in the 2-day composite, the

TABLE 23.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 68 (April, 1904).*

Constituents.	Apr. 27-28.	Apr. 28-29.	Total for 2 days.
(*a*) Weight....grams..	1001.7	843.8	1845.5
(*b*) Water....do...	956.4	795.7	1752.1
(*c*) Solids, *a*—*b*....do...	45.3	48.1	93.4
(*d*) Ash[1]....do...	10.91	11.6	22.51
(*e*) Organic matter, *c* — *d*....do...	34.39	36.50	70.89
(*f*) Nitrogen....do...	12.26	13.03	25.29
(*g*) Carbon....do...	9.75	10.37	20.12
(*h*) Hydrogen in organic matter....do...	2.23	2.38	4.61
(*i*) Oxygen (by difference) in organic matter, $e-(f+g+h)$....do...	10.15	10.72	20.87
(*j*) Heat of combustion....calories...	92	99	191

[1] The ash and water for the individual days are calculated as shown on page 28. Hence the amounts of solids and organic matter for the individual days are not determined but calculated.

same processes were followed as those described in experiment No. 59. The amounts of ash and water for the individual days are affected by the errors in the apportionment of the total solids.

ELIMINATION OF WATER-VAPOR.

The amount of water withdrawn from the respiration chamber by the ventilating air-current varies from period to period and depends in large measure upon the absolute amount of water remaining in the chamber at the end of each period and upon the rate of ventilation. Since as was explained in discussing experiment No. 59 (see page 30) the relative humidity for each period may be readily computed, in table 24 are recorded only the total amount of water-vapor in the atmosphere of the calorimeter at the end of each period and the total water of respiration and perspiration.

On the two days the amount of water lost in respiration and perspiration was essentially the same, there being 745.3 grams on the first day and 760.7 grams on the second.

While in experiment No. 59 there was no recorded change due to loss or gain of water in the weight of the heat-absorbers, chair, bedding, and other articles inside the chamber, in this experiment there was a loss of 47 grams of water on the first day and a gain of 21 grams on the second day. The correct apportionment of this gain or loss of water by individual periods is impracticable, since the weights are taken only once each day. It has therefore been our custom to inspect the hygrometric conditions in the chamber at the end of each period, and thus ascertain whether there was a continuous drying out process or a condensation and absorption of moisture from the air. An inspection of the figures in column *a* in table 24 shows that the water in the respiration chamber

TABLE 24.—*Record of water of respiration and perspiration—Metabolism experiment No. 68.*

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]	Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1904.			1904.		
Apr. 27:	*Grams.*	*Grams.*	Apr. 28–29:	*Grams.*	*Grams.*
Preliminary, 7 a.m....	44.6	....	7 a.m. to 10 a.m......	40.3	100.8
Apr. 27–28:			10 a.m. 1 p.m......	39.4	91.8
7 a.m. to 10 a.m......	46.4	105.3	1 p.m. 4 p.m......	38.2	94.5
10 a.m. 1 p.m......	42.4	95.8	4 p.m. 7 p.m......	38.8	96.6
1 p.m. 4 p.m......	41.2	93.8	7 p.m. 10 p.m......	38.5	91.8
4 p.m. 7 p.m......	41.0	95.2	10 p.m. 1 a.m......	38.6	91.6
7 p.m. 10 p.m......	41.2	90.2	1 a.m. 4 a.m......	46.7	98.0
10 p.m. 1 a.m......	40.5	94.4	4 a.m. 7 a.m......	48.1	95.6
1 a.m. 4 a.m......	38.1	85.9	Total...............	....	760.7
4 a.m. 7 a.m......	38.9	84.7			
Total...............	....	745.3			

[1] Allowance has been made for water lost or gained by the chair, bedding, and miscellaneous articles, as follows: April 27-28, 47.00 grams lost; April 28-29, 21.00 grams gained.

gradually diminished during the first 24 hours. This indicates that the drying out process was continual, hence the 47 grams of water lost from the absorbers, bedding, and other articles was apportioned throughout the eight experimental periods at the rate of 5.88 grams per period.

A consideration of the moisture conditions inside the chamber during the second day, on the other hand, shows that during the period from 1 to 4 a. m. there was a marked change in the water content and hence it is assumed that the 21 grams gained by the absorbers, bedding, etc., was gained during the last two periods of the day. Hence one-half of the total gain was apportioned to each period. Fortunately in this experiment the data for the fluctuations in hygrometric conditions indicate quite clearly during which periods the gain occurred on the second day. Where the exact change in relative humidity

is not marked it is obvious that by this method of apportionment there may be, for example, an apparent loss of water from the absorbers, bed, bedding, and miscellaneous articles during the last period of one day of an experiment and a gain by the same articles in the next period, i. e., the first period of the next experimental day. Until a more perfect method is devised for weighing all the articles in the chamber at the end of each period, this is the only method available for apportioning the 24-hour gain or loss among the different periods.

TABLE 25.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 68.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
		Grams.	*Grams.*	*Liters.*	*Grams.*
1904. Apr. 27......	Preliminary: 7 a. m..	43.7	....	913.6	....
Apr. 27-28...	7 a. m. to 10 a. m..	44.5	110.1	909.7	101.1
	10 a. m. 1 p. m..	52.5	89.3	905.7	76.5
	1 p. m. 4 p. m..	39.0	90.3	904.8	82.3
	4 p. m. 7 p. m..	56.3	93.7	898.0	89.8
	7 p. m. 10 p. m..	39.5	90.2	906.9	84.8
	10 p. m. 1 a. m..	52.0	81.4	892.3	74.9
	1 a. m. 4 a. m..	31.3	67.7	897.9	65.8
	4 a. m. 7 a. m..	51.4	71.6	888.0	64.8
	Total...........	....	694.3	....	640.0
Apr. 28-29...	7 a. m. to 10 a. m..	40.5	98.9	924.1	99.4
	10 a. m. 1 p. m..	38.5	90.2	914.1	83.8
	1 p. m. 4 p. m..	36.2	88.7	903.0	83.7
	4 p. m. 7 p. m..	35.5	92.4	898.1	86.2
	7 p. m. 10 p. m..	36.8	87.7	896.4	81.6
	10 p. m. 1 a. m..	31.6	80.4	896.0	71.8
	1 a. m. 4 a. m..	35.4	70.0	882.7	69.0
	4 a. m. 7 a. m..	39.3	71.0	869.5	67.1
	Total...........	....	679.3	....	642.6

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The elimination of carbon dioxide and the absorption of oxygen were measured in all the experiments reported in this publication. Though the data were given in detail for experiment No. 59 and a separate table was devoted to each, in this and subsequent experiments it will suffice to give only the amounts of oxygen and carbon dioxide in the chamber at the end of each period and the total amounts respired by the subject. Given these data, the proportions of carbon dioxide and oxygen in the air at any given period of the day may be readily computed by the method explained on page 33. The conditions affecting the fluctuations in the amount of oxygen in the chamber have been discussed

previously. They depend in large measure upon the barometric conditions and the temperature, as well as the quantity of nitrogen admitted with the oxygen. Sufficient experimental evidence has accumulated, however, to show that at least under the conditions obtained in these experiments no noticeable effect on the respiratory exchange can be attributed to relatively marked changes in percentages of either carbon dioxide or oxygen in the residual air.

The quantity of carbon dioxide exhaled on the first day, i. e., 694.3 grams, is somewhat larger than that on the second day, 679.3 grams. The quantities of oxygen consumed were practically identical for the two days.

TABLE 26.—*Elements katabolized in body—Metabolism experiment No. 68.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, April 27, 1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	639.99	....	....	....	639.99	....
Outgo:						
Water in urine.............	956.40	....	....	107.02	849.38	....
Solids in urine.............	45.30	12.26	9.75	2.23	10.15	10.91
Water of respiration[1]........	745.31	....	....	83.40	661.91	....
Carbon dioxide............	694.38	....	189.37	....	505.01	....
Total....................	2441.39	12.26	199.12	192.65	2026.45	10.91
Loss....................	1801.40	12.26	199.12	192.65	1386.46	10.91
Second day, April 28, 1904.						
Income: Oxygen from air.......	642.57	....	....	....	642.57	....
Outgo:						
Water in urine............	795.70	....	....	89.04	706.66	....
Solids in urine.............	48.10	13.03	10.37	2.38	10.72	11.60
Water of respiration[1].......	760.74	....	....	85.13	675.61	....
Carbon dioxide............	679.25	....	185.24	....	494.01	....
Total....................	2283.79	13.03	195.61	176.55	1887.00	11.60
Loss....................	1641.22	13.03	195.61	176.55	1244.43	11.60

[1] Includes also water of perspiration.

MATERIAL KATABOLIZED IN THE BODY.

The losses of elements in the body are obtained from chemical analyses of the urine and air. In table 26 are recorded the factors of income and outgo expressed in terms of chemical elements, the ash here being treated as an element. The data are drawn from the preceding tables, and are used as explained on page 37. The balance shows that on the first day there was a loss in total weight of 1801.40 grams, which consisted of 12.26 grams of nitrogen, 199.12 grams of carbon, 192.65 grams of hydrogen, 1386.46 grams of oxygen, and 10.91 grams of ash. Similarly on the second day, the outgo is greater than the income by 1641.22 grams, consisting of 13.03 grams of nitrogen, 195.61 grams of carbon, 176.55 grams of hydrogen, 1244.43 grams of oxygen,

and 11.60 grams of ash. No feces were passed during the time of this experiment, nor were any fasting feces obtainable.

Elements and materials katabolized in the body.—From the data tabulated in table 26, by means of the formulæ on page 38, the amounts of body materials katabolized are obtained. They are recorded, together with the amounts of loss of the several elements, in table 27.

TABLE 27.—*Elements and materials katabolized in body—Metabolism experiment No. 68.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.[1]	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.[1]
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27–28....	12.26	199.12	192.65	1386.46	1460.39	73.56	145.13	112.54	10.91
Apr. 28–29....	13.03	195.61	176.55	1244.43	1319.43	78.18	160.57	72.64	11.60
Total, 2 days.	25.29	394.73	369.20	2630.89	2779.82	151.74	305.70	185.18	22.51

[1] See p. 28.

Table 27 indicates that on the first day the elements lost resulted from the katabolism of 73.56 grams of protein, 145.13 grams of fat, and 112.54 grams of carbohydrates considered as glycogen. On the second day there were katabolized 78.18 grams of protein, 160.57 grams of fat, and 72.64 grams of carbohydrates. There was a marked falling off in the quantity of carbohydrates katabolized on the second day, a slight increase in the amount of protein katabolized and an increased fat katabolism amounting to 15 grams. The rapid diminution in the quantity of carbohydrates katabolized is in accordance with the view that fasting results in the rapid depletion of the store of carbohydrates in the body.

TABLE 28.—*Distribution of intake and outgo of water—Metabolism experiment No. 68.*

Date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c—d).
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.	(e) Intake in drink.	(f) Loss of preformed water (d—e).	
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27–28............	956.4	745.3	1701.7	1460.4	268.4	1192.0	241.3
Apr. 28–29............	795.7	760.7	1556.4	1319.4	616.2	703.2	237.0
Total for 2 days...	1752.1	1506.0	3258.1	2779.8	884.6	1895.2	478.3
Average per day....	876.1	753.0	1629.1	1389.9	442.3	947.6	239.2

Balance of water.—The outgo of water may be considered as of two kinds, preformed water and water resulting from the oxidation of organic hydrogen. Making due allowance for the drinking-water, the quantities of preformed water actually lost from the body tissues and fluids are given in column *f* of table 28. The water resulting from the oxidation of the organic hydrogen in the protein, fats, and carbohydrates katabolized, is given in column *g* of the same table.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

Knowing the factors of the income and the outgo, it should be possible to compute accurately the changes in body-weight, and conversely an accurate measure of the changes of body-weight should serve as a check upon the accuracy of the determinations involved in striking a balance between income and outgo. As a result of much preliminary experimenting, an apparatus was devised by which the subject could be seated in a suspended chair inside the chamber and his weight be recorded on a scale beam outside the calorimeter chamber. This apparatus, which is described in detail elsewhere,[a] has proved more accurate than the ordinary platform scale formerly in use. This weighing apparatus was first put to practical use in the series of experiments which immediately preceded metabolism experiment No. 68.

In the series of experiments here reported, the subjects were weighed each morning at a few minutes after 7 a. m., though the time of weighing and the time consumed in the process was not the same from day to day. While all the subjects urinated after 7 a. m. each morning, some of the subjects urinated before weighing, and hence it seemed desirable to refer all body-weights to exactly 7 a. m., not only to make them more nearly comparable but because the body-weights at exactly this hour are necessary in making the correction for gain or loss of energy due to changes in body-weight. In order, therefore, to refer these weights to 7 a. m. it became necessary to add to the body-weight, as found by the platform scale, the weight of the urine passed after 7 a. m. in case the subject urinated before he was weighed. In cases where the subject was weighed immediately after 7 a. m. and before urinating, the weight as found on the platform scale was taken as the weight at 7 a. m. In experiment No. 68 the subject urinated before weighing.

In table 29 and corresponding tables in subsequent experiments, it will be found that there are slight discrepancies between the gain or loss of body material as estimated and the gain or loss of body-weight as found by the scale. These discrepancies are probably due to a large number of difficulties which arose from the fact that the subjects were not weighed each morning with exactly the same articles of clothing, etc., on their persons. It also happened

[a] Carnegie Institution of Washington Publication No. 42, p. 158.

that on some mornings subjects wore the rectal thermometer while on others they did not. For these and similar reasons it has been a matter of a considerable amount of computation to obtain from the fluctuations in weight as shown by the scale the true fluctuations in weight of the body of the subject.

The comparison for experiment No. 68 of the balance of income and outgo and the fluctuations in weight as shown by the scale are given in table 29.

The intake of the subject consisted solely of drinking-water and oxygen from the air. The outgo consisted of urine, carbon dioxide, and water of respiration and perspiration. As has been stated above, the subjects always urinated after 7 a. m., and hence in obtaining the balance of intake and output from a standpoint of weight the actual time at which the urine is passed must be considered

TABLE 29.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 68.*

Date.	Income.			Outgo.					
	(*a*) Water consumed.	(*b*) Oxygen.	(*c*) Total (*a*+*b*).	(*d*) Urine.[1]	(*e*) Carbon dioxide.	(*f*) Water of respiration and perspiration.	(*g*) Total (*d*+*e*+*f*)	(*h*) Loss of body material (*c*−*g*).	(*i*) Loss of body-weight.
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27–28....	268.4	640.0	908.4	1236.4	694.4	745.3	2676.1	1767.7	1696
Apr. 28–29....	616.2	642.6	1258.8	742.5	679.3	760.7	2182.5	923.7	900
Total, 2 days.	884.6	1282.6	2167.2	1978.9	1373.7	1506.0	4858.6	2691.4	2596
Av. per day..	442.3	641.3	1083.6	989.5	686.8	753.0	2429.3	1345.7	1298

[1] The data in this column should not be confounded with urine data in other tables. (See explanation.)

rather than the period to which the urine physiologically belongs. Thus in column *d* of table 29 the amount of urine—1236.4 grams—does not correspond with the amount—1001.7 grams—shown in line *a* of table 23. The figure 1236.4 grams is the sum of the urine passed as follows: April 27, 7 a. m., 532.2 grams; 1 p. m., 267.5 grams; 7 p. m., 264.6 grams; 11 p. m., 172.1 grams. On the other hand, the figure 1001.7 grams is obtained by the assumption commonly made in metabolism experiments that the urine passed at the end of a given 6-hour period belongs physiologically to that period. For example, the urine passed at 1 p. m. represents the results of katabolism[a] from 7 a. m. to 1 p. m., and 267.5 + 264.6 + 172.1 (see above) + 297.5 (the number of grams passed at 7 a. m., April 28) = 1001.7 grams, the total urine corresponding to the katabolism from 7 a. m., April 27, to 7 a. m., April 28.

[a] The numerous studies on the time relations of protein katabolism show that at least in experiments with food this assumption, though commonly used by all physiologists, is not strictly true.

Column *h* shows the gain or loss of body material to the body, as determined from the data in the previous column of the table. Column *i* shows the gain or loss of body-weight as found by means of the weighing apparatus. In the two days of this experiment, there are discrepancies of considerable size. On the first day the error amounts to over 70 grams and on the second day it is about 24 grams. The difficulty of securing uniformity in the clothing worn, handkerchief, contents of pockets, and other minor articles, especially in the earlier experiments, renders such a discrepancy as here appears not at all surprising, if it be understood that the weight of the subject when undressed was obtained indirectly, i. e., by deducting from the combined weight of the subject, chair, clothing, and bedding, the weight of the chair, clothing, and bedding. The records, though admittedly liable to considerable error, are here given. They show that the agreement is roughly approximate with the computed gain or loss from the income and outgo. Subsequent experiments show this agreement much more strikingly, but up to the present time the greatest difficulty has been to secure absolute uniformity in the miscellaneous articles weighed with the man.

Another factor affecting this determination is that of the loss or gain of moisture by furniture and articles in the respiration chamber. While it is possible to weigh the chair, bedding, and other small articles of furniture, there is a material absorption by loss of moisture from books, papers, minor articles of clothing, etc., and when a relatively large number of these articles are in the chamber, the difficulty in securing accurate weighings is increased. A great difference is noticed among different subjects as regards the quantity of material such as books, papers, etc., required during the different experiments.

Considering all the possible errors arising, it is probably true that the discrepancies between the actual weighings and the computed gain or loss may in almost every instance be attributed to errors in weighing.

OUTPUT OF HEAT.

In order to simplify the explanation of the method of presenting the results of the heat measurements, the data were classified in experiment No. 59 in two tables—one, the "Summary of calorimetric measurements and total heat eliminated"; the other, "Total heat production." In this and all subsequent experiments, however, the results are combined in a single table. The summary data for such computations are given in table 30, in which is recorded first, the heat measured in terms of C_{20}; second, the heat used in the vaporization of water; third, the sum of the other heat corrections [a] referred to above, and finally, the total heat production.

The data for this experiment, corresponding to those of experiment No. 59

[a] For detailed discussion of these corrections and methods of applying them, see discussion in metabolism experiment No. 59, pp. 42 to 49.

and recorded in columns *c, d,* and *e* of table 14, are not shown, but the results of these corrections to the heat eliminated are combined with the correction due to changes of body temperature and body-weight. This latter correction (shown for experiment No. 59 in column *b* of table 17) is not given separate treatment in this and subsequent experiments. The net results of all these corrections are shown in column *c* of table 30.

The heat not measured by the water-current, due to the vaporization of water, was found in experiment No. 59 by multiplying the water vaporized by 0.592. In that experiment the figures given in column *f,* table 14, were identical with the figures given in column *e* of table 5; that is, the water

TABLE 30.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 68.*

Period.	April 27-28, 1904.				April 28-29, 1904.			
	(*a*) Heat measured in terms C_{20}.	(*b*) Heat used in vaporization of water.	(*c*) Sum of heat corrections.[1]	(*d*) Total heat production (*a*+*b*+*c*).	(*a*) Heat measured in terms C_{20}.	(*b*) Heat used in vaporization of water.	(*c*) Sum of heat corrections.[1]	(*d*) Total heat production (*a*+*b*+*c*).
	Cals.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
7 a.m. to 10 a.m.	296.7	65.8	−48.6	313.9	279.6	59.7	−49.3	290.0
10 a.m. 1 p.m.	225.1	60.2	− 0.4	284.9	239.8	54.4	+ 6.4	300.6
1 p.m. 4 p.m.	211.7	59.0	+ 5.1	275.8	234.6	55.9	+ 9.8	300.3
4 p.m. 7 p.m.	230.3	59.9	+13.0	303.2	232.0	57.2	+ 3.1	292.3
7 p.m. 10 p.m.	220.6	56.8	+10.5	287.9	230.1	54.3	− 3.4	281.0
10 p.m. 1 a.m.	181.6	59.3	+28.0	268.9	177.4	54.2	+32.2	263.8
1 a.m. 4 a.m.	163.4	54.4	+ 1.2	219.0	179.8	51.8	+ 6.7	238.3
4 a.m. 7 a.m.	171.0	53.6	−10.8	213.8	187.4	50.4	+13.3	251.1
Total........	1700.4	469.0	− 2.0	2167.4	1760.7	437.9	+18.8	2217.4

[1] See p. 67.

vaporized and the total water of respiration and perspiration were identical. This arose from the fact that in that experiment no correction was made for changes in moisture content of articles inside the calorimeter, as data upon this subject were lacking. In this experiment, however, it should be noted that the heat used in vaporization of water shown in column *b* of table 30 is obtained not by multiplying the total water of respiration and perspiration shown in column *b* of table 24 by 0.592, but by applying this factor to the total amount of water vaporized, since the heat correction has to do not with water of respiration and perspiration but with water actually vaporized in the chamber during the period. So far as the heat measurements are concerned, it is immaterial whether the water be vaporized from the surface of the man or the bed-clothing or elsewhere inside the chamber. On the other hand, a true measure of water of respiration and perspiration from the body of the subject for each period should make due allowance for changes in water content of the various articles in the chamber.

The amount of water vaporized does not appear either in table 30 or in the table recording the data concerning water-vapor, i. e., table 24, but it may be computed by adding to the total water of respiration and perspiration the amount of water lost by the chair, bedding, and absorbers, or if these latter gain water, by subtracting the amount gained from the total water of respiration and perspiration.

The heat produced on the two days of this experiment, recorded in column *d*, is nearly the same, there being an increase of but 50 calories on the second day over the first. The uniformity of the heat production signifies a close approximation to constant muscular activity.

BALANCE OF ENERGY.

The total energy resulting from the katabolism of protein, fat, and glycogen on the different days is shown for this and the following experiments in exactly the same form in table 31 as for experiment No. 59. Since the source of the figures was explained in detail (see p. 51), further explanation seems unnecessary. It may be well, however, again to call attention to the fact that while fat and glycogen are completely oxidized in the body and their energy converted to kinetic energy, in the case of the protein, there is an appreciable part of the energy excreted in a partially unoxidized form, namely, in the unoxidized compounds of the urine. In order, therefore, to construct a complete balance of the energy derived from all sources with the total heat production, it is necessary to take into consideration the potential energy of the urine.

TABLE 31.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 68.*

Date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater (+) or less (—) than output.	
	From body protein.			(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).		(h) Amount (f—g).	(i) Proportion (h÷g).
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).						
1904.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Apr. 27-28....	416	92	324	1385	472	2181	2167	+14	+0.6
Apr. 28-29....	442	99	343	1532	304	2179	2217	—38	—1.7
Total, 2 days.	858	191	667	2917	776	4360	4384	—24	....
Av. per day..	429	96	333	1459	388	2180	2192	—12	—0.5

On the first day of the experiment, the energy derived from the different sources is computed to be 14 calories larger than the total heat production, a disagreement of +0.6 per cent. On the second day, on the contrary, the energy derived from the different sources is computed to be 38 calories less than the total heat produced, a discrepancy of —1.7 per cent. The average of the two days gives a discrepancy of but 12 calories, which is —0.5 per cent of the total heat production.

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The oxygen and carbon dioxide thermal quotients and the respiratory quotients for the different periods of the two experimental days of experiment No. 68 are given in table 32.

TABLE 32.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 68.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f ÷ g).
1904. Apr. 27:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Preliminary, 7 a.m.	....	....	....	....	....	....	....	....
Apr. 27–28:								
7 a.m. to 10 a.m.	313.9	101.1	32.2	110.1	35.1	56.0	70.7	0.79
10 a.m. 1 p.m.	284.9	76.5	26.9	89.3	31.4	45.5	53.6	.85
1 p.m. 4 p.m.	275.8	82.3	29.9	90.3	32.8	46.0	57.6	.80
4 p.m. 7 p.m.	303.2	89.8	29.6	93.7	30.9	47.7	62.9	.76
7 p.m. 10 p.m.	287.9	84.8	29.5	90.2	31.3	45.9	59.4	.77
10 p.m. 1 a.m.	268.9	74.9	27.9	81.4	30.3	41.4	52.4	.79
1 a.m. 4 a.m.	219.0	65.8	30.0	67.7	30.9	34.5	46.0	.75
4 a.m. 7 a.m.	213.8	64.8	30.3	71.6	33.5	36.5	45.4	.80
Total	2167.4	640.0	29.5	694.3	32.0	353.5	448.0	.79
Apr. 28–29:								
7 a.m. to 10 a.m.	290.0	99.4	34.3	98.9	34.1	50.4	69.6	.72
10 a.m. 1 p.m.	300.6	83.8	27.9	90.2	30.0	45.9	58.7	.78
1 p.m. 4 p.m.	300.3	83.7	27.9	88.7	29.6	45.2	58.6	.77
4 p.m. 7 p.m.	292.3	86.2	29.5	92.4	31.6	47.0	60.3	.78
7 p.m. 10 p.m.	281.0	81.6	29.1	87.7	31.2	44.6	57.1	.78
10 p.m. 1 a.m.	263.8	71.8	27.2	80.4	30.5	40.9	50.2	.82
1 a.m. 4 a.m.	238.3	69.0	28.9	70.0	29.4	35.7	48.3	.74
4 a.m. 7 a.m.	251.1	67.1	26.7	71.0	28.3	36.1	47.0	.77
Total	2217.4	642.6	29.0	679.3	30.6	345.8	449.8	.77

The same discrepancies which have been pointed out before as obtaining for the determinations of oxygen, heat, and carbon dioxide during short periods vitiate the accuracy of the ratios for individual periods, yet the results for 24 hours are probably accurate. The oxygen thermal quotient remains nearly constant for the two days, falling from 29.5 on the first day to 29.0 on the second day. The carbon dioxide thermal quotient indicates a somewhat greater fall, varying from 32.0 on the first day to 30.6 on the second day. The respiratory quotient, although indicating marked fluctuations in the different periods, on the average for the 24 hours is 0.79 for the first day and 0.77 for the second.

METABOLISM EXPERIMENT NO. 69.

This experiment, which continued for 4 days, was made with the same subject as experiment No. 68, but 7 months later. The subject entered the respiration chamber on the evening of December 15, 1904, the experiment proper beginning at 7 a. m., December 16. Preliminary practice in adjustment of furniture and apparatus inside the calorimeter chamber was not necessary, as this subject had previously participated in a large number of experiments. He was also thoroughly accustomed to the environment. The usual clothing was worn and the general plan of the whole experiment was similar to that of experiment No. 68.

It has already been suggested that A. L. L., the subject of this experiment, was of phlegmatic temperament. The following notes from his diary contain practically everything he wrote, and so brief are they that their value for deduction as to the physical or psychical condition of the subject ~~was~~ practically is worthless. They simply serve to indicate that the stay in the calorimeter was not distasteful to the subject and that he felt little ill effect from his fast.

Notes from diary.

Dec. 16, 1904:
Lay down this morning at 9 and remained on the bed until 1 p. m. Slept the greater part of the time, but with disturbed dreams during the last of it.

Dec. 17, 1904:
While adjusting the heat absorbers this morning, I felt a little faint. Have had no desire for water, but have drunk as ordered.[*]

Dec. 18, 1904:
Nothing worthy of note regarding this day.

Dec. 19, 1904:
Day passed quite as the rest.

Pulse.—In this experiment the subject counted his pulse twice each day. The count was made for two minutes and the average number of beats per minute is recorded below.

Time.	Pulse rate.	Time.	Pulse rate.
Dec. 16, 1904, $1^h\ 00^m$ p. m..	55	Dec. 18, 1904, $7^h\ 45^m$ a. m..	62
8 15 p. m..	52	11 00 p. m..	48
Dec. 17, 1904, 9 50 a. m..	57	Dec. 19, 1904, 8 30 a. m..	62
3 00 p. m..	62	10 20 p. m..	56

Routine.—Aside from conforming to the general experimental period so far as hours of sleep, rising, collection of urine, etc., was concerned, the subject was allowed to do as he pleased except that he was cautioned to secure, in so far as possible, uniform muscular activity on the several days of the experiment.

[*] Owing to the unusually high specific gravity of the urine of this subject in previous experiments he was requested to drink liberal amounts of water.

Body movements.—A careful record was kept of the bodily activity, and for the better interpretation of the results it is given herewith.

Movements of subject.—Duration, 4 days, from Dec. 16, 7 a. m., to Dec. 20, 7 a. m., 1904.

December 16.

A. M.	
$7^h\,00^m$	rise.
7 02	weigh self.
7 04	weigh absorbers.
7 06	dress.
7 10	urinate.
7 18	fold bed.
7 20	adjust table, sit.
7 24	read, sit.
8 06	telephone.
8 08	read.
9 08	recline, read.
9 16	stop reading.
9 36	asleep.
P. M.	
$12^h\,52^m$	awake, read.
1 00	telephone.
1 02	rise, urinate, sit.
1 10	food aperture.
1 24	count pulse.
1 30	write.
2 26	telephone.
2 28	food aperture.
2 30	read.
4 22	telephone.
4 28	telephone.
4 30	read.
7 00	urinate.
7 02	read.
7 04	telephone.
7 05	food aperture.
7 06	read.
8 15	count pulse.
11 00	urinate.
11 06	retire.

December 17.

A. M.	
$7^h\,00^m$	rise.
7 02	weigh self.
7 04	weigh absorbers.
7 08	urinate.
7 10	dress.
7 16	sit.
7 20	read.
7 30	food aperture.
7 32	read.
$8^h\,04^m$	telephone.
8 06	read.
8 36	stop reading.
9 06	lie, read.
9 50	count pulse.
10 36	telephone, food aperture.
10 42	lie.
11 30	stop reading.
11 36	asleep.
P. M.	
$1^h\,02^m$	rise, urinate, food aperture.
1 04	sit, read.
3 00	count pulse.
3 54	telephone.
3 56	drink.
4 04	telephone.
5 06	close curtain.
5 10	open curtain, sit.
5 14	telephone.
5 16	read.
6 24	food aperture.
6 28	read.
7 02	urinate.
7 06	read.
11 08	urinate.
11 10	retire.

December 18.

A. M.	
$7^h\,02^m$	rise.
7 04	weigh self.
7 06	weigh absorbers.
7 12	urinate, food aperture.
7 14	dress.
7 24	read.
7 45	count pulse.
9 10	lie, read.
10 30	telephone.
10 32	sit, food aperture.
10 40	lie, read.
P. M.	
$12^h\,58^m$	rise, sit.
1 00	urinate, food aperture.
$1^h\,02^m$	read.
1 20	food aperture.
2 24	stop reading.
2 26	write.
6 26	telephone.
6 32	food aperture.
7 02	urinate.
7 06	food aperture.
7 08	read.
9 02	read.
9 38	asleep.
11 00	count pulse.
11 02	urinate, retire.

December 19.

A. M.	
$7^h\,00^m$	rise.
7 04	weigh self.
7 06	weigh absorbers.
7 10	urinate.
7 12	dress.
7 15	food aperture.
7 16	sit.
7 25	food aperture.
8 10	telephone.
8 14	food aperture.
8 20	write.
8 30	count pulse.
8 37	food aperture.
8 44	read.
9 08	lie.
9 44	asleep.
11 02	telephone.
11 04	sit, food aperture.
11 06	lie, read.
P. M.	
$1^h\,02^m$	rise, urinate, food aperture.
1 04	sit, read.
2 23	food aperture.
3 54	telephone.
7 04	telephone, urinate, food aperture.
7 06	read.
10 20	count pulse.
11 00	urinate, undress, retire.

Drinking-water.—During this experiment the subject did not appear to care for water and would have drunk very little of his own accord. In previous experiments he had shown a similar tendency, and in some instances the quantity of urine voided had been very small and of a high specific gravity.

Accordingly the subject was requested to drink considerable amounts of water and no doubt consumed more than he desired, though it gave him no discomfort. The daily amounts consumed and the estimates for the water consumed by periods during the experiment are given in table 33.

In estimating the quantity of water consumed during each of the periods for which the amounts were not definitely shown, it was assumed that after a weighed amount of water was placed in the calorimeter chamber equal amounts were drunk during each 2-hour period until all this water was consumed. For example, it was known that between the hours of 1 and 7 p. m. on December 16 the subject drank 489.10 grams of water. These 6 hours constituted three experimental periods and it was assumed that one-third of this amount (163.03) grams of water was taken during each period. While the apportionment of the quantities for the different periods is at best but roughly approximate, it must be borne in mind that the absolute amount of water taken during the day was determined with accuracy. A similar apportionment has been made of the water consumed on the subsequent days of the experiment.

TABLE 33.—*Record of water consumed—Metabolism experiment No. 69.*

Date.	Period during which water was consumed.[1]								Total for day.
	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 16–17...	38.33	....	....	163.04	163.03	163.03	119.60	....	647.03
Dec. 17–18...	166.04	....	166.03	....	166.03	55.50	....	....	553.60
Dec. 18–19...	148.00	148.00	148.00	163.00	163.00	162.90	76.20	76.20	1085.30
Dec. 19–20...	136.37	136.37	136.36	131.80	....	131.80	77.90	77.90	828.50

[1] Assumed in some instances. (See above.)

URINE.

As in experiment No. 68, the urine was collected 4 times daily. In the samples of urine thus collected a number of determinations were made which are recorded in table 34. As a check on the nitrogen determinations the total nitrogen was determined in the daily composite as well as by periods.

Weight and composition of urine.—In addition to the determinations of nitrogen, specific gravity and reaction made upon urine collected by periods, there were determined in the daily composite the water, total solids, ash, nitrogen, carbon, hydrogen in organic matter, phosphorus, sulphur, and heat of combustion. From the weight of urine and the percentages obtained in the above determinations, the total amounts of each ingredient analyzed were computed. These amounts are recorded in table 35.

While in experiments Nos. 59 and 68 determinations of ash, carbon, and hydrogen were made only on the composite urine for the whole experiment, in

this experiment the determinations were made on each daily sample, thus avoiding the complicated and somewhat erroneous calculations for the distribution or apportionment of the water, ash, solids, carbon, and hydrogen over the individual days of the experiment.

TABLE 34.—*Determinations in urine per period and per day—Metabolism experiment No. 69.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a÷b).	(d) Reaction.	(e) Nitrogen.
1904.		*Grams.*		*c. c.*		*Grams.*
Dec. 16–17.	7 a.m. to 1 p.m.	115.4	1.0320	112	Acid.....	2.45
	1 p.m. 7 p.m.	123.3	1.0330	119	..do......	2.51
	7 p.m. 11 p.m.	63.1	1.0360	61	..do......	1.52
	11 p.m. 7 a.m.	150.0	1.0335	145	..do......	3.61
	Total......	451.8	....	437	....	10.09
	Total by composite...	451.8	1.0330	437	....	9.95
Dec. 17–18.	7 a.m. to 1 p.m.	174.4	1.0280	169	Acid.....	3.94
	1 p.m. 7 p.m.	167.9	1.0280	163	.. do......	3.80
	7 p.m. 11 p.m.	92.2	1.0325	89	.. do......	2.39
	11 p.m. 7 a.m.	155.6	1.0325	151	.. do......	4.13
	Total....	590.1	....	572	....	14.26
	. Total by composite...	590.1	1.0310	572	....	14.34
Dec. 18–19.	7 a.m. to 1 p.m.	255.9	1.0205	250	Acid.....	4.32
	1 p.m. 7 p.m.	208.2	1.0255	203	..do......	4.03
	7 p.m. 11 p.m.	107.9	1.0265	105	..do......	2.34
	11 p.m. 7 a.m.	190.3	1.0270	185	..do......	4.35
	Total................	762.3	....	743	....	15.04
	Total by composite...	762.3	1.0250	743	....	15.03
Dec. 19–20.	7 a.m. to 1 p.m.	250.2	1.0195	245	Acid.....	4.12
	1 p.m. 7 p.m.	227.9	1.0215	223	..do......	3.47
	7 p.m. 11 p.m.	100.9	1.0265	98	..do......	2.23
	11 p.m. 7 a.m.	163.1	1.0280	159	..do......	3.15
	Total................	742.1	....	725	....	12.97
	Total by composite...	742.1	1.0230	725	....	13.18
	Total, 4 days.........	2546.3	....	2477	....	52.36

The determinations of phosphorus were made by fusion with sodium peroxide and not by titration with uranium salts. For purposes of further comparison the quantity of phosphorus is expressed in line *j* of table 35 as the element and in line *k* as phosphoric acid, i. e., phosphorus pentoxide. The amounts of sulphur are likewise expressed both as sulphur and as sulphur trioxide.

ELIMINATION OF WATER-VAPOR.

The amounts of water-vapor remaining in the chamber at the end of each 2-hour period are recorded in table 36, together with the amounts of water of respiration and perspiration. On the preliminary night, the residual amounts

were determined in two periods of 3 hours each immediately preceding the experiment. In this experiment as in experiment No. 68, there were certain changes in the weights of the chair, bed, bedding, etc. The amounts of water involved in these changes are noted at the end of the table. While inspection of the humidity conditions in this experiment showed that the losses must have been fairly regular for the first, third, and fourth days, the gain on the second day apparently occurred during the last 4 periods of the day and it was so apportioned.

TABLE 35.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 69.*

	Dec. 16-17.	Dec. 17-18.	Dec. 18-19.	Dec. 19-20.	Total for 4 days.
(a) Weight................grams..	451.8	590.01	762.3	742.1	2546.3
(b) Water....................do....	415.75	545.08	714.81	700.32	2375.96
(c) Solids, $a-b$..............do....	36.05	45.02	47.49	41.78	170.34
(d) Ash......................do....	6.64	6.43	6.56	5.57	25.20
(e) Organic matter, $c-d$......do....	29.41	38.59	40.93	36.21	145.14
(f) Nitrogen..................do....	10.09	14.26	15.04	12.97	52.36
(g) Carbon ....do....	8.31	9.97	10.37	9.42	38.07
(h) Hydrogen in organic matter, grams......................	1.81	2.66	2.67	2.45	9.59
(i) Oxygen (by difference) in organic matter, $e-(f+g+h)$....grams..	9.20	11.70	12.85	11.37	45.12
(j) Phosphorus..............do....	.409	.520	.463	.455	1.847
(k) Phosphoric acid by fusion (P_2O_5), grams......................	.936	1.192	1.060	1.043	4.231
(l) Sulphur................grams..	.550	.738	.837	.790	2.915
(m) Sulphur trioxide (SO_3).....do....	1.374	1.844	2.089	1.971	7.278
(n) Heat of combustion....calories..	92	112	120	110	434

The total water of respiration and perspiration in this experiment varied considerably from day to day. On the second day there were 160 grams more water vaporized from the lungs and skin than on the first, while on the last day the amount of water was slightly less than on the first.

Cutaneous excretion of nitrogenous material.—During this experiment and No. 70 following, the subject wore continuously a union suit and a pair of stockings which had been previously thoroughly washed and extracted with distilled water. Before the experiment began the subject washed himself thoroughly without using soap. He then took a shower bath and finally sponged his whole body with clean cheesecloth and distilled water. After the termination of experiment No. 70 the water used to extract the clothing and sponge the body of the subject contained 0.722 gram of nitrogen, corresponding to an elimination of 0.013 gram per day for the 7 days the subject was in the respiration chamber. This excretion of nitrogen has not been considered in any of the computations.

As has been pointed out elsewhere,[a] the cutaneous excretion of nitrogenous material is a factor to be considered in metabolism experiments. Especially

TABLE 36.—*Record of water of respiration and perspiration—Metabolism experiment No. 69.*

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]	Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1904.			1904.		
Dec. 16:			Dec. 18–19:	*Grams.*	*Grams.*
Preliminary:	*Grams.*	*Grams.*	7 a.m. to 9 a.m....	44.9	80.3
1 a.m.	49.9	....	9 a.m. 11 a.m....	43.1	67.4
1 a.m. to 4 a.m.....	46.4	130.6	11 a.m. 1 p.m....	43.6	69.4
4 a.m. 7 a.m.....	47.8	116.7	1 p.m. 3 p.m....	42.0	63.9
Total............	....	247.3	3 p.m. 5 p.m....	39.2	65.3
			5 p.m. 7 p.m....	41.1	67.1
Dec. 16–17:			7 p.m. 9 p.m....	38.5	65.1
7 a.m. to 9 a.m....	44.3	75.2	9 p.m. 11 p.m....	37.7	59.7
9 a.m. 11 a.m....	41.0	59.8	11 p.m. 1 a.m....	36.4	60.3
11 a.m. 1 p.m....	40.6	61.0	1 a.m. 3 a.m....	43.4	70.0
1 p.m. 3 p.m....	39.4	61.0	3 a.m. 5 a.m....	45.8	73.8
3 p.m. 5 p.m....	36.7	58.6	5 a.m. 7 a.m....	42.6	52.6
5 p.m. 7 p.m....	35.2	54.9	Total............	....	794.9
7 p.m. 9 p.m....	33.8	58.4			
9 p.m. 11 p.m....	34.5	55.6	Dec. 19–20:		
11 p.m. 1 a.m....	36.8	60.6	7 a.m. to 9 a.m....	42.5	70.8
1 a.m. 3 a.m....	39.4	60.3	9 a.m. 11 a.m....	37.5	55.6
3 a.m. 5 a.m....	41.1	67.2	11 a.m. 1 p.m....	38.1	61.8
5 a.m. 7 a.m....	43.9	65.8	1 p.m. 3 p.m....	38.6	59.2
Total............	....	738.4	3 p.m. 5 p.m ...	37.4	62.0
			5 p.m. 7 p.m....	39.0	61.9
Dec. 17–18:			7 p.m. 9 p.m....	36.7	61.2
7 a.m. to 9 a.m....	46.9	84.9	9 p.m. 11 p.m....	37.0	59.1
9 a.m. 11 a.m....	44.9	68.9	11 p.m. 1 a.m....	36.5	60.5
11 a.m. 1 p.m....	40.7	64.2	1 a.m. 3 a.m....	36.5	58.0
1 p.m. 3 p.m....	41.8	66.9	3 a.m. 5 a.m....	36.9	61.5
3 p.m. 5 p.m....	41.9	69.3	5 a.m. 7 a.m....	36.1	56.4
5 p.m. 7 p.m....	43.2	71.0	Total............	....	728.0
7 p.m. 9 p.m....	41.2	67.7			
9 p.m. 11 p.m....	40.3	65.2			
11 p.m. 1 a.m....	46.5	85.0			
1 a.m. 3 a.m....	51.2	89.2			
3 a.m. 5 a.m....	51.5	88.7			
5 a.m. 7 a.m....	44.5	77.4			
Total............	....	898.4			

[1] Allowance is made for water gained or lost by chair, bedding, and miscellaneous articles as follows: December 16-17, 55.70 grams lost; December 17-18, 23.30 grams gained; December 18-19, 29.70 grams lost; December 19-20, 34.80 grams lost.

is this true in experiments in which work is performed where the nitrogen of organic matter excreted through the skin may amount to 0.22 gram of

[a] Journ. of Biological Chemistry, 1906, 1, p. 263.

TABLE 37.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 69.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1904.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Dec. 16......	1 a. m.............	31.4	....	922.0	.....
	1 a. m. to 4 a. m..	26.2	68.8	910.3	66.4
	4 a. m. 7 a. m..	33.0	77.3	901.3	70.0
	Total	....	146.1	....	136.4
Dec. 16-17...	7 a. m. to 9 a. m..	35.1	67.2	918.6	56.1
	9 a. m. 11 a. m..	33.5	48.1	917.2	43.1
	11 a. m. 1 p. m..	31.5	49.6	923.2	41.6
	1 p. m. 3 p. m..	38.5	58.5	918.7	57.6
	3 p. m. 5 p. m..	32.1	52.5	933.3	49.4
	5 p. m. 7 p. m..	34.4	53.0	941.3	49.4
	7 p. m. 9 p. m..	33.2	58.6	946.3	52.8
	9 p. m. 11 p. m..	37.3	53.0	944.0	52.2
	11 p. m. 1 a. m..	29.7	49.0	945.1	45.4
	1 a. m. 3 a. m..	34.4	46.8	942.5	47.3
	3 a. m. 5 a. m..	30.7	48.2	943.1	46.8
	5 a. m. 7 a. m..	36.5	47.3	932.7	42.5
	Total...........	....	631.8	....	584.2
Dec. 17-18...	7 a. m. to 9 a. m..	40.9	73.6	934.1	74.1
	9 a. m. 11 a. m..	47.2	56.9	933.6	53.4
	11 a. m. 1 p. m..	34.9	49.4	931.8	49.0
	1 p. m. 3 p. m..	49.4	60.3	918.2	62.8
	3 p. m. 5 p. m..	40.8	60.4	920.1	54.1
	5 p. m. 7 p. m..	53.0	63.3	903.7	58.1
	7 p. m. 9 p. m..	40.1	57.3	903.3	58.4
	9 p. m. 11 p. m..	49.2	56.4	892.8	47.8
	11 p. m. 1 a. m..	36.5	53.7	870.2	50.2
	1 a. m. 3 a. m..	43.8	45.8	848.1	46.2
	3 a. m. 5 a. m..	35.0	44.6	846.3	43.1
	5 a. m. 7 a. m..	29.9	44.7	864.1	48.6
	Total...........	....	666.4	....	645.8
Dec. 18-19...	7 a. m. to 9 a. m..	36.8	72.4	870.5	67.9
	9 a. m. 11 a. m..	38.5	55.2	880.4	50.3
	11 a. m. 1 p. m..	35.7	57.0	885.6	58.9
	1 p. m. 3 p. m..	40.5	57.0	891.5	54.6
	3 p. m. 5 p. m..	35.5	56.8	907.1	54.1
	5 p. m. 7 p. m..	39.0	57.8	914.3	50.1
	7 p. m. 9 p. m..	34.2	54.1	917.7	58.8
	9 p. m. 11 p. m..	36.1	50.7	918.7	47.0
	11 p. m. 1 a. m..	28.2	47.6	922.5	48.2
	1 a. m. 3 a. m..	29.7	40.6	913.5	42.7
	3 a. m. 5 a. m..	27.4	46.2	902.6	45.5
	5 a. m. 7 a. m..	36.0	45.3	921.9	41.3
	Total...........	....	640.7	....	619.4

TABLE 37.—*Continued.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1904		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Dec. 19-20...	7 a. m. to 9 a. m..	37.6	68.3	920.6	67.0
	9 a. m. 11 a. m..	37.8	46.0	915.6	46.0
	11 a. m. 1 p. m..	32.8	53.8	900.7	52.5
	1 p. m. 3 p. m..	41.9	55.3	893.5	52.9
	3 p. m. 5 p. m..	33.1	54.5	905.0	53.8
	5 p. m. 7 p. m..	43.7	55.2	892.1	53.9
	7 p. m. 9 p. m..	33.5	52.9	900.2	54.8
	9 p. m. 11 p. m..	42.1	52.7	893.2	50.7
	11 p. m. 1 a. m..	29.6	45.0	896.8	41.0
	1 a. m. 3 a. m..	35.8	41.7	902.7	43.5
	3 a. m. 5 a. m..	29.8	42.9	905.7	42.2
	5 a. m. 7 a. m..	39.1	44.3	907.3	42.9
	Total............	....	612.6	....	601.2

nitrogen per hour. At the time these determinations were made the computations of these rest experiments, in which very small amounts of nitrogen existed in the cutaneous excretions, were so far advanced that to revise them and allow for the nitrogen thus excreted would have involved a great amount of labor. It was deemed inadvisable to incur the added expense of making these changes and hence in all the experiments here reported no allowance for the cutaneous excretion of nitrogenous material has been made.

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The carbon dioxide and oxygen were determined during each 2-hour period save for the preliminary night, when the periods were 3 hours long. The data recorded in table 37 show the amounts in the chamber at the end of each period, the carbon dioxide being expressed in grams and the oxygen in liters, and also the total weight of both carbon dioxide exhaled and oxygen consumed by the subject per period and daily. As has been pointed out before, these data are sufficient for computing the proportion of either carbon dioxide or oxygen in the air at any given period.

The total amounts of both carbon dioxide and oxygen during the different days of the experiment follow approximately the total amount of water-vapor eliminated, i. e., on the second day of the experiment the largest amount of water and carbon dioxide were exhaled and oxygen consumed, while on the first and last days minimum amounts were observed.

ELEMENTS KATABOLIZED IN THE BODY.

From the chemical analyses the elements of income and outgo are determined and from these in turn the material katabolized in the body expressed in

TABLE 38.—*Material katabolized in body—Metabolism experiment No. 69.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Dec. 16, 1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	584.22	....	....	....	584.22	....
Outgo:						
Water in urine	415.75	....	....	46.52	369.23	....
Solids in urine	36.05	10.09	8.31	1.81	9.20	6.64
Water of respiration [1]	738.34	....	....	82.62	655.72	....
Carbon dioxide	631.75	....	172.30	....	459.45	....
Total	1821.89	10.09	180.61	130.95	1493.60	6.64
Loss	1237.67	10.09	180.61	130.95	909.38	6.64
Second day, Dec. 17, 1904.						
Income: Oxygen from air	645.80	....	....	....	645.80	....
Outgo:						
Water in urine	545.08	....	....	60.99	484.09	....
Solids in urine	45.02	14.26	9.97	2.66	11.70	6.43
Water of respiration [1]	898.36	....	....	100.53	797.83	....
Carbon dioxide	666.40	....	181.74	....	484.66	....
Total	2154.86	14.26	191.71	164.18	1778.28	6.43
Loss	1509.06	14.26	191.71	164.18	1132.48	6.43
Third day, Dec. 18, 1904.						
Income: Oxygen from air	619.41	....	....	....	619.41	....
Outgo:						
Water in urine	714.81	....	....	79.99	634.82	....
Solids in urine	47.49	15.04	10.37	2.67	12.85	6.56
Water of respiration [1]	794.93	....	....	88.95	705.98	....
Carbon dioxide	640.68	....	174.73	....	465.95	....
Total	2197.91	15.04	185.10	171.61	1819.60	6.56
Loss	1578.50	15.04	185.10	171.61	1200.19	6.56
Fourth day, Dec. 19, 1904.						
Income: Oxygen from air	601.21	....	....	....	601.21	....
Outgo:						
Water in urine	700.32	....	....	78.37	621.95	....
Solids in urine	41.78	12.97	9.42	2.45	11.37	5.57
Water of respiration [1]	727.95	....	....	81.46	646.49	....
Carbon dioxide	612.64	....	167.09	....	445.55	....
Total	2082.69	12.97	176.51	162.28	1725.36	5.57
Loss	1481.48	12.97	176.51	162.28	1124.15	5.57

[1] Includes also water of perspiration.

elements is computed. The data are shown in table 38. No feces were passed during the time of this experiment.

Elements and materials katabolized from the body.—The elements katabolized from the body are recorded in the first part of the summary table 39,

and the quantities of water, protein, fat, and carbohydrates which were katabolized in the body, as computed from the formulæ, are recorded in the latter part of the table. The katabolism of protein increased markedly on the second and third days, and decreased on the fourth day. The katabolism of fat increased on the second day, after which the amounts remained nearly constant. The loss of glycogen is by far the largest on the first day, and is

TABLE 39.—*Elements and materials katabolized in body—Metabolism experiment No. 69.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 16–17....	10.09	180.61	130.95	909.38	932.76	60.54	134.87	103.79	6.64
Dec. 17–18....	14.26	191.71	164.18	1132.48	1212.57	85.56	174.29	31.52	6.43
Dec. 18–19....	15.04	185.10	171.61	1200.19	1288.69	90.24	161.67	32.72	6.56
Dec. 19–20....	12.97	176.51	162.28	1124.15	1214.83	77.82	169.16	15.29	5.57
Total, 4 days.	52.36	733.93	629.02	4366.20	4648.85	314.16	639.99	183.32	25.20

smallest on the fourth day. The amounts katabolized on the second and third days were practically identical.

Balance of water.—According to the computations recorded in table 39, there is a large loss of water to the body during each experimental day, but no

TABLE 40.—*Distribution of intake and outgo of water—Metabolism experiment No. 69.*

Date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c—d).
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.	(e) Intake in drink.	(f) Loss of preformed water (d—e).	
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 16–17............	415.7	738.3	1154.0	932.7	647.0	285.7	221.3
Dec. 17–18............	545.1	898.4	1443.5	1212.6	553.6	659.0	230.9
Dec. 18–19............	714.8	794.9	1509.7	1288.7	1085.3	203.4	221.0
Dec. 19–20............	700.3	728.0	1428.3	1214.8	828.5	386.3	213.5
Total, 4 days......	2375.9	3159.6	5535.5	4648.8	3114.4	1534.4	886.7
Average per day...	594.0	789.9	1383.9	1162.2	778.6	383.6	221.7

allowance has been made for the drinking-water and hence the actual loss to the body of preformed water is less than that recorded in column *e* of table 39 by the amount of drinking-water consumed each day. Thus on the third day, while there is an apparent loss of water from the body amounting to 1288.69 grams, the subject actually drank 1085.30 grams. Hence the actual loss to the body for this particular day was but a little over 200 grams or only

one-sixth of the amount apparently lost. The amounts of water ingested and eliminated, together with the losses of preformed water and water of oxidation of organic hydrogen, are shown in detail in table 40.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

With increased accuracy in the use of the special scale attached to the respiration calorimeter, weights of the subject, absorbers, chair, bedding, and clothing were taken each morning at a specified time. These weights have been compared with the different factors of income and outgo, and a balance has

TABLE 41.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 69.*

	Dec. 16-17.	Dec. 17-18.	Dec. 18-19.	Dec. 19-20.	Total for 4 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Water consumed	647.08	553.60	1085.30	828.50	3114.48	778.61
(*b*) Oxygen	584.22	645.80	619.41	601.21	2450.64	612.66
(*c*) Total ($a+b$)	1231.25	1199.40	1704.71	1429.71	5565.07	1391.27
Outgo:						
(*d*) Urine.[1]	538.42	584.50	727.60	769.30	2619.82	654.96
(*e*) Carbon dioxide	631.75	666.40	640.68	612.64	2551.47	637.87
(*f*) Water of respiration and perspiration	738.34	898.36	794.93	727.95	3159.58	789.89
(*g*) Total ($d+e+f$)	1908.51	2149.26	2163.21	2109.89	8330.87	2082.72
(*h*) Loss (−) of body material ($c-g$)	−677.26	−949.86	−458.50	−680.18	−2765.80	−691.45
(*i*) Loss (−) of body-weight	−654.00	−979.00	−459.00	−762.00	−2854.00	−713.50

[1] The data in this line should not be confounded with urine data in other tables. (See explanation, p. 66.)

been struck which is given in table 41. The total income of the subject consists of water and oxygen consumed, while his total outgo is the quantity of urine passed, carbon dioxide exhaled, and water of respiration and perspiration.

Save on the last day the discrepancies appearing in table 41 are not great, the average showing a marked improvement over the results obtained in experiment No. 68. The average loss per day as computed is less by 22 grams than that obtained by use of the weighing apparatus, an error which is altogether too large for accurate work.

OUTPUT OF HEAT.

A summarized record of the measurements made with the calorimeter, the heat used in vaporization of water and the sum of the heat corrections, together with the total heat production, is given in table 42.

The amount of heat produced daily is comparable with the amounts of water-vapor, carbon dioxide, and oxygen in that the smaller amounts of each are found on the first and last days of the experiment, and larger amounts on the second and third days.

TABLE 42.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 69.*

Period.	Dec. 16-17, 1904.				Dec. 17-18, 1904.			
	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
	Cals.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
7 a.m. to 9 a.m.	191.7	47.3	−36.9	202.1	202.2	50.2	−32.5	219.9
9 a.m. 11 a.m.	109.9	38.1	−28.8	119.2	125.2	40.8	+21.4	187.4
11 a.m. 1 p.m.	95.0	38.9	+13.6	147.5	115.6	38.0	−14.4	139.2
1 p.m. 3 p.m.	148.0	38.8	+20.4	207.2	157.0	39.6	+27.6	224.2
3 p.m. 5 p.m.	131.5	37.5	+ 4.4	173.4	151.8	41.0	− 4.9	188.0
5 p.m. 7 p.m.	126.3	35.2	+15.3	176.8	149.2	42.1	+25.1	216.4
7 p.m. 9 p.m.	132.8	37.3	− 3.7	166.4	142.8	40.1	−12.4	170.5
9 p.m. 11 p.m.	128.3	35.7	− 4.4	159.6	149.4	38.6	− 4.0	184.0
11 p.m. 1 a.m.	96.1	38.6	+ 5.8	140.5	126.6	46.8	+ 4.0	177.4
1 a.m. 3 a.m.	98.9	38.4	+ 9.0	146.3	109.9	49.3	−13.8	145.4
3 a.m. 5 a.m.	113.8	42.6	− 1.5	154.9	99.8	49.0	− 1.2	147.6
5 a.m. 7 a.m.	101.4	41.7	+14.2	157.3	103.3	42.4	+17.0	162.7
Total.......	1473.7	470.1	+ 7.4	1951.2	1632.9	518.0	+11.8	2162.7
	Dec. 18-19, 1904.				Dec. 19-20, 1904.			
7 a.m. to 9 a.m.	180.0	49.0	−19.6	209.4	176.0	43.7	−27.4	192.3
9 a.m. 11 a.m.	123.7	41.3	+ 1.7	166.7	110.9	34.6	+ 8.0	153.5
11 a.m. 1 p.m.	119.6	42.6	+13.1	175.3	116.4	38.3	+17.0	171.7
1 p.m. 3 p.m.	154.9	39.3	− 7.5	186.7	144.2	36.8	− 0.1	180.9
3 p.m. 5 p.m.	149.0	40.2	− 0.5	188.7	134.2	38.4	+ 5.0	177.6
5 p.m. 7 p.m.	143.5	41.2	+ 9.6	194.3	137.3	38.4	+ 3.2	178.9
7 p.m. 9 p.m.	144.9	40.0	− 8.3	176.6	138.3	38.0	− 0.3	176.0
9 p.m. 11 p.m.	139.7	36.8	−10.6	165.9	136.3	36.7	−13.4	159.6
11 p.m. 1 a.m.	91.9	37.2	+62.4	191.5	91.6	37.5	+20.0	149.1
1 a.m. 3 a.m.	104.1	42.9	−19.4	127.6	120.0	36.0	− 9.1	146.9
3 a.m. 5 a.m.	98.4	45.1	− 8.1	135.4	93.5	38.1	− 1.5	130.1
5 a.m. 7 a.m.	105.1	32.6	−20.5	117.2	94.8	35.1	+11.6	141.5
Total.......	1554.8	488.2	− 7.7	2035.3	1493.5	451.6	+13.0	1958.1

[1] See pp. 42-49.

BALANCE OF ENERGY.

The total heat produced in the body shown in table 42 should equal the total amount of heat due to the oxidation of body materials, and hence the two are compared in table 43. In this particular experiment, the computed energy derived from different sources is greater in all cases than the total heat production, varying from 3 calories on the second day to 50 calories on the fourth day, or from 0.1 per cent to 2.6 per cent.

TABLE 43.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 69.*

Date.	Energy derived from different sources. From body protein. (a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).	(g) Total heat production.	Energy from body material greater (+) or less (—) than output. (h) Amount (f—g).	(i) Proportion (h÷g).
1904.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Dec. 16–17....	342	92	250	1287	435	1972	1951	+ 21	+1.1
Dec. 17–18....	483	112	371	1663	132	2166	2163	+ 3	+0.1
Dec. 18–19....	510	120	390	1542	137	2069	2035	+ 34	+1.7
Dec. 19–20....	440	110	330	1614	64	2008	1958	+ 50	+2.6
Total, 4 days.	1775	434	1341	6106	768	8215	8107	+108	....
Av. per day..	444	109	335	1527	192	2054	2027	+ 27	+1.3

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The ratios as expressed by the oxygen thermal quotient, carbon dioxide thermal quotient, and respiratory quotient for the different periods of the experiment are given in table 44. Noticeable fluctuations appear in the quotients for the different periods. On the other hand, the quotients for 24 hours are nearly constant.

TABLE 44.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 69.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
1904. Dec. 16: Preliminary:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1 a.m. to 4 a.m.	....	66.4	....	68.8	....	35.0	46.5	0.75
4 a.m. 7 a.m.	....	70.0	....	77.3	....	39.4	49.0	.80
Total.........	....	136.4	....	146.1	....	74.4	95.5	.78
Dec. 16–17:								
7 a.m. to 9 a.m.	202.1	56.1	27.8	67.2	33.3	34.2	39.3	.87
9 a.m. 11 a.m.	119.2	43.1	36.2	48.1	40.4	24.5	30.2	.81
11 a.m. 1 p.m.	147.5	41.6	28.2	49.6	33.6	25.3	29.1	.87
1 p.m. 3 p.m.	207.2	57.6	27.8	58.5	28.2	29.8	40.3	.74
3 p.m. 5 p.m.	173.4	49.4	28.5	52.5	30.3	26.7	34.6	.77
5 p.m. 7 p.m.	176.8	49.4	27.9	53.0	30.0	27.0	34.6	.78
7 p.m. 9 p.m.	166.4	52.8	31.7	58.6	35.2	29.8	36.9	.81
9 p.m. 11 p.m.	159.6	52.2	32.7	53.0	33.2	27.0	36.5	.74
11 p.m. 1 a.m.	140.5	45.4	32.3	49.0	34.9	24.9	31.8	.79
1 a.m. 3 a.m.	146.3	47.3	32.3	46.8	32.0	23.8	33.1	.72
3 a.m. 5 a.m.	154.9	46.8	30.3	48.2	31.1	24.5	32.8	.75
5 a.m. 7 a.m.	157.3	42.5	27.0	47.3	30.1	24.1	29.8	.81
Total.........	1951.2	584.2	29.9	631.8	32.4	321.6	409.0	.79

TABLE 44.—*Continued.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
1904. Dec. 17–18:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m. to 9 a.m.	219.9	74.1	33.7	73.6	33.5	37.5	51.9	0.72
9 a.m. 11 a.m.	187.4	53.4	28.5	56.9	30.4	29.0	37.4	.78
11 a.m. 1 p.m.	139.2	49.0	35.2	49.4	35.5	25.2	34.3	.73
1 p.m. 3 p.m.	224.2	62.8	28.0	60.3	26.9	30.7	43.9	.70
3 p.m. 5 p.m.	188.0	54.1	28.8	60.4	32.1	30.7	37.9	.81
5 p.m. 7 p.m.	216.4	58.1	26.8	63.3	29.2	32.2	40.7	.79
7 p.m. 9 p.m.	170.5	58.4	34.3	57.3	33.6	29.2	40.9	.71
9 p.m. 11 p.m.	184.0	47.8	26.0	56.4	30.6	28.7	33.5	.86
11 p.m. 1 a.m.	177.4	50.2	28.3	53.7	30.2	27.3	35.1	.78
1 a.m. 3 a.m.	145.4	46.2	31.8	45.8	31.5	23.3	32.4	.72
3 a.m. 5 a.m.	147.6	43.1	29.2	44.6	30.2	22.7	30.1	.75
5 a.m. 7 a.m.	162.7	48.6	29.9	44.7	27.5	22.8	34.0	.67
Total.........	2162.7	645.8	29.9	666.4	30.8	339.3	452.1	.75
Dec. 18–19:								
7 a.m. to 9 a.m.	209.4	67.9	32.4	72.4	34.6	36.9	47.6	.78
9 a.m. 11 a.m.	166.7	50.3	30.2	55.2	33.1	28.1	35.2	.80
11 a.m. 1 p.m.	175.3	58.9	33.6	57.0	32.5	29.0	41.2	.70
1 p.m. 3 p.m.	186.7	54.6	29.3	57.0	30.5	29.0	38.3	.76
3 p.m. 5 p.m.	188.7	54.1	28.7	56.8	30.1	28.9	37.9	.76
5 p.m. 7 p.m.	194.3	50.1	25.8	57.8	29.8	29.5	35.0	.84
7 p.m. 9 p.m.	176.6	58.8	33.3	54.1	30.6	27.5	41.2	.67
9 p.m. 11 p.m.	165.9	47.0	28.3	50.7	30.6	25.8	32.9	.79
11 p.m. 1 a.m.	191.5	48.2	25.2	47.6	24.8	24.2	33.7	.72
1 a.m. 3 a.m.	127.6	42.7	33.5	40.6	31.9	20.7	29.9	.69
3 a.m. 5 a.m.	135.4	45.5	33.6	46.2	34.2	23.5	31.8	.74
5 a.m. 7 a.m.	117.2	41.3	35.2	45.3	38.7	23.1	28.9	.80
Total.........	2035.3	619.4	30.4	640.7	31.5	326.2	433.6	.75
Dec. 19–20:								
7 a.m. to 9 a.m.	192.3	67.0	34.9	68.3	35.6	34.8	46.9	.74
9 a.m. 11 a.m.	153.5	46.0	30.0	46.0	30.0	23.4	32.2	.73
11 a.m. 1 p.m.	171.7	52.5	30.6	53.5	31.3	27.4	36.8	.75
1 p.m. 3 p.m.	180.9	52.9	29.3	55.3	30.6	28.2	37.1	.76
3 p.m. 5 p.m.	177.6	53.8	30.3	54.5	30.7	27.8	37.6	.74
5 p.m. 7 p.m.	178.9	53.9	30.1	55.2	30.9	28.1	37.7	.75
7 p.m. 9 p.m.	176.0	54.8	31.1	52.9	30.1	26.9	38.3	.70
9 p.m. 11 p.m.	159.6	50.7	31.8	52.7	33.0	26.8	35.5	.76
11 p.m. 1 a.m.	149.1	41.0	27.5	45.0	30.2	22.9	28.7	.80
1 a.m. 3 a.m.	146.9	43.5	29.6	41.7	28.4	21.2	30.4	.70
3 a.m. 5 a.m.	130.1	42.2	32.5	42.9	33.0	21.8	20.6	.74
5 a.m. 7 a.m.	141.5	42.9	30.4	44.3	31.3	22.6	30.1	.75
Total.........	1958.1	601.2	30.7	612.6	31.3	311.9	420.9	.74

METABOLISM EXPERIMENT NO. 70.

Metabolism experiment No. 70, which differs from those previously reported in this publication in that food was eaten, offers opportunity to study in connection with the effect of inanition upon metabolism the effect of the subsequent ingestion of food.

In order to accumulate data in regard to the interrelations of fasting and eating on metabolism, several such experiments were made, the subject remaining inside the respiration chamber throughout both the fasting and the food periods. Experiments Nos. 69 and 70 together form the first series of this type.

After 4 such series of experiments had been made, however, this method of observation was discontinued for the following reasons. The results of a large number of experiments had shown that the transition from the fasting to a food period must not be too abrupt. This conforms with the experience of all professional fasters, who practice a gradual transition in order to readjust their bodies to the digestion of food. But since one of the important factors in studying metabolism by means of the respiration chamber is to secure a preliminary condition more or less uniform with that obtaining during the experiment itself, it was obvious that, on the transition day at least, the metabolic processes of the body have a transitional activity between that of complete fasting and of full digestion of food, and hence the processes of metabolism during the first day or two were not uniform. Moreover, it became apparent that there was a tendency on the part of the subjects to shorten the duration of the fasting period when they realized that after the fast there would still remain a 2- or 3-day stay in the chamber.

The interpretation of the results of metabolism experiments and the computations showing the material katabolized in the body, the proportions of nutrients absorbed from the food ingested and the gains or losses to the body may be made according to many methods. In the fasting experiments the method of computation is relatively simple, as the only factor involved is the amount of material actually katabolized. But on the contrary, when food is ingested, and especially in that class of experiments in which the ingestion of food immediately follows fasting, the conditions are not as satisfactory for employing the method commonly used in metabolism experiments. It is commonly assumed that when a metabolism experiment is made during which the subject is subsisting on a constant diet, the contents of the alimentary tract are in general constant, i. e., the absorption of food is continuous in that the proportions of ingested protein, fat, and carbohydrates in the alimentary tract do not indicate marked variations from day to day. In such cases, it may be assumed that at the beginning of the experiment and at the end like conditions

obtain in the alimentary tract as well as in the tissues. But on the other hand, in the experiments in which food is ingested after fasting, it is certainly true that during the transitional period, there is unlike absorption from the alimentary tract, and probably not until two or more days have passed will the conditions be comparable to those of the ordinary metabolism experiment.

A further factor enters into computations of this nature in that it has commonly been assumed that the chemical elements and compounds in the feces result entirely from unabsorbed food. This is equivalent to saying that the feces are not a true excretory product, but simply residues of undigested food. More recent research is showing that, with certain diets at least, this is far from being the case and that the compounds in the feces are the result of metabolic changes just as surely as are the compounds in the urine.[a]

Until more satisfactory methods for distinguishing between the undigested residues of food in the feces and the products of metabolic changes have been developed, no other alternative presents itself in these computations than to assume that the materials in the feces are undigested food. According to this assumption the actual amount of material absorbed from the food by the body is the difference between the actual weight of the chemical compounds and elements in the food and the weight of the corresponding elements and compounds in the feces.

It is commonly accepted that all the compounds in the urine result from metabolic activity and yet it is to be borne in mind that preformed extractives, such as creatinine, may be excreted in this manner without undergoing a change.

As a result of the analyses of urine and respiratory products, as well as the determinations of heat, it is possible to determine the actual katabolism in the body, irrespective of the ingestion of food. Having determined to what extent katabolism has taken place, it is then proper to compare the ingredients of the absorbed food with the corresponding materials katabolized and see in how far the food has sufficed to replace the material broken down. This comparison will also serve to show whether there has been an excess of food and consequent storage of material. In discussing the food experiments made in connection with the study of the influence of inanition on metabolism, the plan will therefore be adopted of first calculating the amount of material katabolized and then determining to what extent the food supplied the necessary material for katabolism.

In deciding upon a method for recording results of experiments with food, the fact was taken into consideration that the actual katabolism was the most important phase studied. By means of the analyses of urine and the respiratory

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[a] For a further discussion of this phase of computing metabolism experiments, see U. S. Dept. Agr., Office of Expt. Sta. Bul. 175.

products, this katabolism can be determined with reasonable accuracy without the introduction of the numerous errors incidental to the methods of computation involving the use of food and feces; for not only the errors in the preparation and sampling of food and separation of feces, but other incidental errors at present seemingly inevitable, creep into all methods of computation in which analyses of food and feces are used. Hence it may be said that by the determination of the actual katabolism from the analyses of the urine and respiratory gases, a considerable portion of such errors may be eliminated. The statement above regarding the errors incidental to the treatment of food and feces affects, however, as fully in this as in any other method of computation the subsequent comparison of the absorption of food with the katabolism.

Experiment No. 70, which continued for 3 days, immediately followed the 4-day fasting experiment, No. 69, and began at 7 a. m., December 20, 1904.

The following notes from the diary of the subject, A. L. L., contain practically all the available information concerning his subjective impressions:

Notes from diary.

Dec. 20, 1904:
Sat on the bed most of the time; didn't get to sleep until past 12 o'clock.

Dec. 21, 1904:
My eyes were in such a condition that I was unable to read, so lay down most of the evening. Did not go to sleep until about 12 and awoke at a little after 3. The only real satisfactory sleep I had for the rest of the night was an hour just before being called.

Dec. 22, 1904: [a]

Pulse.—The pulse rate was taken by the subject but twice during this experiment. At 8 a. m., December 21, the pulse rate per minute was 86, and at 10 p. m. of the same day it was 88.

Body movements.—The records of body movements are given below.

Movements of subject.—Duration, 3 days, from Dec. 20, 7 a. m., to Dec. 23, 7 a. m., 1904.

December 20.

Time	Movement
A. M.	
7^h 00^m	rise.
7 02	weigh.
7 08	finish weighing.
7 10	urinate, dress.
7 16	sit.
7 20	food aperture.
7 22	drink.
7 26	read, sit.
7 48	telephone.
10 00	telephone.
10 02	food aperture.
10 04	drink.
10 06	lie, read.
P. M.	
12^h 00^m	telephone.
12 02	sit.
12 04	read.
12 18	food aperture.
12 20	drink.
12 22	lie, read.
1 00	sit.
1 02	food aperture.
1 03	urinate.
1 04	read.
2 10	food aperture.
2 12	read.
3 12	food aperture.
3 18	drink.
3 24	read.
P. M.	
4^h 14^m	recline.
4 20	sit.
4 22	read.
5 14	telephone.
5 40	telephone.
5 44	food aperture.
5 48	telephone.
5 52	drink.
5 56	food aperture.
7 02	drink.
7 03	urinate.
7 08	read.
7 24	food aperture.
11 04	urinate, undress, etc., retire.

[a] No record.

December 21.

A. M.
7h 00m rise.
7 04 weigh.
7 14 dress.
7 15 urinate.
7 20 sit.
7 44 telephone, food aperture.
8 54 read.
9 02 lie, read.
10 04 sit, drink.
10 06 lie, read.
10 30 telephone.
10 32 sit, food aperture.
10 40 lie, read.
11 44 sit, food aperture.
11 50 drink.

P. M.
12h 02m read.
1 00 telephone, sit, urinate.
1 04 read.
3 02 telephone.
3 04 write.
3 08 read.
4 18 food aperture.
4h 20m drink.
4 24 read.
7 00 urinate.
9 06 food aperture.
9 25 food aperture.
11 00 close curtain, undress, etc., retire.

December 22.

A. M.
7h 00m rise.
7 04 weigh.
7 12 finish weighing.
7 14 urinate.
7 16 dress.
7 36 food aperture.
8 00 count pulse.
8 18 read.
9 18 lie, read.
10 26 sit, food aperture.
10 32 drink.
10 34 lie.
10 38 read.

P. M.
1h 02m sit, urinate.
1 40 food aperture.
1 42 drink.
3h 02m lie.
3 24 stop reading.
3 40 read.
4 04 stop reading.
4 24 lie.
4 36 asleep.
5 00 telephone, rise, food aperture.
5 02 take temperature.
5 10 recline.
5 22 read.
5 38 sit, food aperture.
5 42 drink.
5 52 recline.
6 08 read.
7 02 sit, urinate.
7 06 lie.
7 14 telephone.
7 30 close curtain.
7 40 defecate, open curtain.
8 43 food aperture.
10 00 read, count pulse.
11 00 close curtain, urinate, undress, etc., retire.

TABLE 45.—*Record of water consumed—Metabolism experiment No. 70.*

Date.	Period during which water was consumed.[1]				
	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	5 to 7 p. m.	Total for day.
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 20–21.......	125.1	....	10.3	3.6	139.0
Dec. 21–22.......	103.7	207.3	....	....	311.0
Dec. 22–23.......	114.7	229.3	....	....	344.0

[1] Assumed in some instances.

Drinking-water.—The diet during this experiment contained a considerable proportion of milk, which probably accounts for the fact that the amount of water consumed was small. The actual amounts per day and the estimated amounts drunk during those 2-hour periods when water was taken are given in table 45.

URINE.

The usual system of collecting the urine was continued, and such determinations as were made on the samples taken during each period are recorded in table 46.

The quantities of elements and compounds determined in the composite urine of each day are tabulated in table 47.

TABLE 46.—*Determinations in urine per period and per day—Metabolism experiment No. 70.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a÷b).	(d) Reaction.	(e) Nitrogen.
1904.		*Grams.*		*c. c.*		*Grams.*
Dec. 20–21.	7 a.m. to 1 p.m.	350.6	1.0135	346	Acid.........	3.69
	1 p.m. 7 p.m.	382.4	1.0140	377	....do........	3.92
	7 p.m. 11 p.m.	149.7	1.0205	147	....	2.43
	11 p.m. 7 a.m.	148.8	1.0260	144	Acid.........	3.00
	Total..........	1031.5	....	1014	....	13.04
	Total by composite........	1031.5	1.0170	1014	....	12.99
Dec. 21–22.	7 a.m. to 1 p.m.	196.5	1.0120	194	Acid.........	1.21
	1 p.m. 7 p.m.	515.9	1.0145	509	....do........	4.34
	7 p.m. 11 p.m.	195.6	1.0170	192	....do........	2.02
	11 p.m. 7 a.m.	134.7	1.0280	131	....do........	2.27
	Total..........	1042.7	....	1026	....	9.84
	Total by composite.........	1042.7	1.0165	1026	....	9.75
Dec. 22–23.	7 a.m. to 1 p.m.	178.0	1.0220	174	Acid.........	2.58
	1 p.m. 7 p.m.	216.8	1.0255	211	....do........	3.15
	7 p.m. 11 p.m.	93.8	1.0280	91	....do........	1.71
	11 p.m. 7 a.m.	136.1	1.0350	132	....do........	2.71
	Total..........	624.7	....	608	....	10.15
	Total by composite........	624.7	1.0270	608	....	10.17
	Total, 3 days....	2698.9	....	2648	....	33.03

TABLE 47.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 70.*

	Dec. 20-21.	Dec. 21-22.	Dec. 22-23.	Total for 3 days.
(a) Weight......................grams..	1031.5	1042.7	624.7	2698.9
(b) Water..........................do...	991.37	1007.04	586.16	2584.57
(c) Solids, *a*—*b*....................do...	40.13	35.66	38.54	114.33
(d) Ash............................do...	4.54	6.36	8.93	19.83
(e) Organic matter, *c*—*d*............do...	35.59	29.30	29.61	94.50
(f) Nitrogen.......................do...	13.04	9.84	10.15	33.03
(g) Carbon.........................do...	8.87	7.51	8.12	24.50
(h) Hydrogen in organic matter.......do...	2.37	1.88	2.00	6.25
(i) Oxygen (by difference) in organic matter, $e-(f+g+h)$.........grams..	11.31	10.07	9.34	30.72
(j) Phosphorus.....................do...	.640	.651	.405	1.696
(k) Phosphoric acid by fusion (P_2O_5)..do...	1.465	1.491	.929	3.885
(l) Sulphur........................do...	.724	.597	.691	2.012
(m) Sulphur trioxide (SO_3)...........do...	1.808	1.490	1.724	5.022
(n) Heat of combustion..........calories..	103	82	91	276

ELIMINATION OF WATER-VAPOR.

The total water of respiration and perspiration is tabulated in table 48. Contrary to the results usually obtained in fasting experiments, there is an increase from one day to another in the water eliminated. The relative humidity may be obtained by the method previously explained.

TABLE 48.—*Record of water of respiration and perspiration—Metabolism experiment No. 70.*

Date.	Period.	(a) Total am'nt of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1904.		*Grams.*	*Grams.*
	Preliminary:		
Dec. 20....	5 a.m. to 7 a.m.	36.1	....
Dec. 20-21.	7 a.m. to 9 a.m.	38.7	75.0
	9 a.m. 11 a.m.	39.9	66.8
	11 a.m. 1 p.m.	38.9	67.0
	1 p.m. 3 p.m.	41.7	65.1
	3 p.m. 5 p.m.	36.9	64.6
	5 p.m. 7 p.m.	37.8	71.0
	7 p.m. 9 p.m.	37.3	65.9
	9 p.m. 11 p.m.	37.2	66.7
	11 p.m. 1 a.m.	40.0	72.5
	1 a.m. 3 a.m.	46.1	90.9
	3 a.m. 5 a.m.	39.7	70.6
	5 a.m. 7 a.m.	33.2	64.2
	Total......	....	840.3
Dec. 21-22.	7 a.m. to 9 a.m.	37.7	75.7
	9 a.m. 11 a.m.	37.2	72.8
	11 a.m. 1 p.m.	38.5	71.3
	1 p.m. 3 p.m.	36.7	73.1
	3 p.m. 5 p.m.	40.2	81.9
	5 p.m. 7 p.m.	44.7	90.2
1904.		*Grams.*	*Grams.*
Dec. 21-22.	7 p.m. to 9 p.m.	46.2	101.1
	9 p.m. 11 p.m.	43.7	88.2
	11 p.m. 1 a.m.	46.1	95.2
	1 a.m. 3 a.m.	47.9	95.8
	3 a.m. 5 a.m.	42.0	83.9
	5 a.m. 7 a.m.	36.5	73.6
	Total......	....	1002.8
Dec. 22-23.	7 a.m. to 9 a.m.	40.4	86.8
	9 a.m. 11 a.m.	39.1	79.6
	11 a.m. 1 p.m.	39.5	76.9
	1 p.m. 3 p.m.	36.9	70.5
	3 p.m. 5 p.m.	33.8	69.9
	5 p.m. 7 p.m.	45.7	97.9
	7 p.m. 9 p.m.	51.1	105.0
	9 p.m. 11 p.m.	42.5	86.9
	11 p.m. 1 a.m.	55.3	103.9
	1 a.m. 3 a.m.	54.0	110.5
	3 a.m. 5 a.m.	47.0	90.1
	5 a.m. 7 a.m.	39.3	81.1
	Total......	....	1059.1

[1] Allowance has been made for water gained by the chair, bedding, and miscellaneous articles as follows: December 20-21, 5.26 grams; December 21-22, 30.22 grams; December 22-23, 43.32 grams. (See p. 61.)

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The data indicated by this heading are reported in table 49. The continual daily increase in the amounts is noticeable.

Material katabolized in the body.—Although food as well as water was ingested in this experiment, the computations by which the materials katabolized are obtained are in no wise different from those in experiments without food. The reason for this method of computation will appear from a consideration of the status of water drunk in fasting experiments. As has already been explained, in the latter type of experiment the computations omit water from the intake because only the oxygen is capable of entering into chemical

combination. Later a comparison is made to show in how far the water drunk compensated for the outgo. So, too, in food experiments the food is considered independently from katabolism, and the attempt is made to show to what

TABLE 49.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 70.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1904.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Dec. 20......	5 a. m. to 7 a. m..	39.1	....	907.3	....
Dec. 20–21...	7 a. m. to 9 a. m..	33.5	63.6	913.5	63.4
	9 a. m. 11 a. m..	51.2	60.1	899.5	56.9
	11 a. m. 1 p. m..	38.0	55.5	898.4	54.1
	1 p. m. 3 p. m..	55.6	59.7	882.0	57.2
	3 p. m. 5 p. m..	39.1	57.2	889.4	51.7
	5 p. m. 7 p. m..	33.0	60.1	888.3	59.5
	7 p. m. 9 p. m..	37.3	60.0	881.7	56.2
	9 p. m. 11 p. m..	30.8	53.5	878.6	52.8
	11 p. m. 1 a. m..	28.8	51.4	871.5	49.3
	1 a. m. 3 a. m..	26.8	49.1	871.1	48.9
	3 a. m. 5 a. m..	28.0	41.6	879.1	37.0
	5 a. m. 7 a. m..	22.0	41.1	907.0	35.4
	Total...........	....	652.9	....	622.4
Dec. 21–22...	7 a. m. to 9 a. m..	36.7	66.5	910.5	70.4
	9 a. m. 11 a. m..	31.3	58.0	918.1	54.2
	11 a. m. 1 p. m..	33.0	58.9	927.1	56.5
	1 p. m. 3 p. m..	30.0	57.3	941.0	53.6
	3 p. m. 5 p. m..	33.7	65.4	956.2	84.2
	5 p. m. 7 p. m..	31.8	65.3	963.4	59.1
	7 p. m. 9 p. m..	32.6	62.9	966.6	62.6
	9 p. m. 11 p. m..	33.5	63.6	973.2	59.2
	11 p. m. 1 a. m..	31.4	54.9	974.7	53.5
	1 a. m. 3 a. m..	25.5	45.6	972.5	35.3
	3 a. m. 5 a. m..	26.8	44.6	981.2	41.4
	5 a. m. 7 a. m..	22.0	42.6	984.5	41.2
	Total...........	....	685.6	....	671.2
Dec. 22–23...	7 a. m. to 9 a. m..	38.2	72.5	972.6	74.0
	9 a. m. 11 a. m..	34.1	63.3	974.4	58.0
	11 a. m. 1 p. m..	35.9	66.9	961.5	60.2
	1 p. m. 3 p. m..	38.1	63.8	960.7	56.4
	3 p. m. 5 p. m..	32.2	63.3	963.7	62.2
	5 p. m. 7 p. m..	34.5	73.4	946.0	72.5
	7 p. m. 9 p. m..	40.2	72.6	926.4	67.9
	9 p. m. 11 p. m..	34.1	66.8	941.2	63.9
	11 p. m. 1 a. m..	34.5	64.3	913.0	62.9
	1 a. m. 3 a. m..	31.8	57.0	918.6	48.2
	3 a. m. 5 a. m..	34.7	59.9	910.9	62.9
	5 a. m. 7 a. m..	29.8	53.6	925.0	43.8
	Total...........	....	777.4	....	732.9

extent the food retrieves material lost from the body. Hence oxygen in the air is here considered as the sole source of income.

TABLE 50.—*Elements katabolized in body—Metabolism experiment No. 70.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Dec. 20, 1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	622.40	....	....	....	622.40	....
Outgo:						
Water in urine............	991.37	....	....	110.94	880.43	....
Solids in urine............	40.13	1304	8.87	2.37	11.31	4.54
Water of respiration [1].......	840.30	....	....	94.03	746.27	....
Carbon dixoide............	652.86	....	178.05	....	474.81	....
Total..................	2524.66	13.04	186.92	207.34	2112.82	4.54
Loss..................	1902.26	13.04	186.92	207.34	1490.42	4.54
Second day, Dec. 21, 1904.						
Income: Oxygen from air......	671.25	....	....	....	671.25	....
Outgo:						
Water in urine............	1007.04	....	....	112.69	894.35	....
Solids in urine............	35.66	9.84	7.51	1.88	10.07	6.36
Water of respiration [1].......	1002.78	....	....	112.21	890.57	....
Carbon dioxide............	685.63	....	187.00	....	498.63	....
Total..................	2731.11	9.84	194.51	226.78	2293.62	6.36
Loss..................	2059.86	9.84	194.51	226.78	1622.37	6.36
Third day, Dec. 22, 1904.						
Income: Oxygen from air......	732.89	....	....	....	732.89	....
Outgo:						
Water in urine............	586.16	....	....	65.59	520.57	....
Solids in urine............	38.54	10.15	8.12	2.00	9.34	8.93
Water of respiration [1].......	1059.07	....	....	118.51	940.56	....
Carbon dioxide............	777.43	....	212.03	....	565.40	....
Total..................	2461.20	10.15	220.15	186.10	2035.87	8.93
Loss..................	1728.31	10.15	220.15	186.10	1302.98	8.93

[1] Includes also water of perspiration.

TABLE 51.—*Elements and materials katabolized in body—Metabolism experiment No. 70.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 20–21....	13.04	186.92	207.34	1490.42	1605.63	78.24	158.59	56.46	4.54
Dec. 21–22....	9.84	194.51	226.78	1622.37	1765.54	59.04	193.87	35.95	6.36
Dec. 22–23....	10.15	220.15	186.10	1302.98	1870.61	60.90	188.90	99.90	8.93
Total, 3 days.	33.03	601.58	620.22	4415.77	4741.78	198.18	541.36	192.31	19.83

The results for the total materials katabolized expressed as chemical elements are given in table 50, and in table 51 the corresponding body compounds are shown. It is important to remember in interpreting these tables that no account has as yet been taken of the materials in the food or drink.

OUTPUT OF HEAT.

The total heat production, together with the data from which it is computed, is recorded in table 52. The steady increase in the heat production during

TABLE 52.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 70.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1904.		Calories.	Calories.	Calories.	Calories.
Dec. 20–21..........	7 a.m. to 9 a.m......	172.4	44.1	− 5.0	211.5
	9 a.m. 11 a.m......	132.6	39.3	+13.9	185.8
	11 a.m. 1 p.m......	122.2	39.4	+21.3	182.9
	1 p.m. 3 p.m......	141.6	38.3	− 8.7	171.2
	3 p.m. 5 p.m......	149.8	38.0	+ 8.6	196.4
	5 p.m. 7 p.m......	151.3	41.8	+ 3.1	196.2
	7 p.m. 9 p.m......	148.4	38.7	+ 5.0	192.1
	9 p.m. 11 p.m......	132.4	39.2	− 1.5	170.1
	11 p.m. 1 a.m......	115.6	42.7	+18.2	176.5
	1 a.m. 3 a.m......	112.3	53.6	−17.8	148.1
	3 a.m. 5 a.m......	118.1	41.6	− 6.8	152.9
	5 a.m. 7 a.m......	98.9	37.7	−16.5	120.1
	Total..............	1595.6	494.4	+13.8	2103.8
Dec. 21–22..........	7 a.m. to 9 a.m......	156.2	43.3	+24.0	223.5
	9 a.m. 11 a.m......	121.3	41.6	+12.3	175.2
	11 a.m. 1 p.m......	119.0	40.7	+19.6	179.3
	1 p.m. 3 p.m......	155.5	41.7	− 0.8	196.4
	3 p.m. 5 p.m......	142.6	47.0	+17.3	206.9
	5 p.m. 7 p.m......	141.9	51.9	+29.5	223.3
	7 p.m. 9 p.m......	160.4	58.4	−28.9	189.9
	9 p.m. 11 p.m......	138.9	50.7	− 6.1	183.5
	11 p.m. 1 a.m......	139.1	54.9	− 0.1	193.9
	1 a.m. 3 a.m......	102.5	55.2	− 2.6	155.1
	3 a.m. 5 a.m......	100.8	48.2	− 6.6	142.4
	5 a.m. 7 a.m......	93.7	42.1	+18.2	154.0
	Total..............	1571.9	575.7	+75.8	2223.4
Dec. 22–23..........	7 a.m. to 9 a.m......	170.1	49.2	−11.6	207.7
	9 a.m. 11 a.m......	125.6	45.0	+27.7	198.3
	11 a.m. 1 p.m......	121.0	43.4	+34.4	198.8
	1 p.m. 3 p.m......	142.6	39.6	+35.2	217.4
	3 p.m. 5 p.m......	145.3	39.2	+13.7	198.2
	5 p.m. 7 p.m......	155.6	55.8	+ 3.5	214.9
	7 p.m. 9 p.m......	164.2	60.1	+24.3	248.6
	9 p.m. 11 p.m......	149.2	49.3	+ 2.4	200.9
	11 p.m. 1 a.m......	132.1	59.4	+18.1	209.6
	1 a.m. 3 a.m......	158.9	63.3	−35.0	187.2
	3 a.m. 5 a.m	180.3	51.2	− 9.5	222.0
	5 a.m. 7 a.m......	143.8	45.8	−36.6	153.0
	Total..............	1788.7	601.3	+66.6	2456.6

[1] See pp. 42-49.

the 3 days of the experiment, which is fully in accord with the similar increase observed in the carbon dioxide and water output and oxygen consumption, is an added indication of increased katabolism.

BALANCE OF ENERGY.

Recognizing that the energy derived was from body material rather than from food (for it is commonly assumed that the protein, fats, and carbohydrates of our diet must first be transformed into body fluid or body tissue before they are oxidized), an energy balance may be obtained. In accordance with this assumption it is proper to compare the heat production with the total heat of combustion of body materials oxidized (making allowance for the incomplete oxidation of protein) in food experiments exactly as in experiments without food. Such a comparison is given in table 53. The total heat production when compared with the total computed heat resulting from the katabolism of body material shows an agreement which is in the main very satisfactory.

TABLE 53.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 70.*

Date.	Energy derived from different sources. From body protein. (a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).	(g) Total heat production.	Energy from body material greater (+) or less (—) than output. (h) Amount (f—g).	(i) Proportion (h+g).
1904.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Dec. 20–21....	442	103	339	1513	237	2089	2104	—15	—0.7
Dec. 21–22....	334	82	252	1850	151	2253	2223	+30	+1.3
Dec. 22–23....	344	91	253	1802	419	2474	2457	+17	+0.7
Total, 3 days.	1120	276	844	5165	807	6816	6784	+32	....
Av. per day..	373	92	281	1722	269	2272	2261	+11	+0.5

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The computation of the ratios between the respiratory gases and the heat production is made precisely as in a fasting experiment. The results are given in table 54. The agreements between the different periods are reasonably close with the exception of the abnormally low quotient 0.565 (!) found in the fifth period of the second day. No adequate explanation of this discrepancy has as yet appeared.

EFFECT OF INGESTION OF FOOD.

Having considered the katabolism of body material, it is next proper to consider to what extent the food supplied the materials and energy for restoring the material and energy lost.

Diet.—Recognizing that a simple diet is advantageous in breaking a prolonged fast, the diet in this experiment consisted of milk, together with a

small quantity of plasmon (a milk product). The milk used was "modified" by a large admixture of cream, and separate analyses of it were made each day.

TABLE 54.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 70.*

Date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d × 0.5091).	(g) Volume of oxygen consumed (b × 0.7).	(h) Respiratory quotient (f ÷ g)
1904.		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Dec. 20–21.	7 a.m. to 9 a.m.	211.5	63.4	30.0	63.6	30.1	32.4	44.4	0.73
	9 a.m. 11 a.m.	185.8	56.9	30.6	60.1	32.3	30.6	39.8	.77
	11 a.m. 1 p.m.	182.9	54.1	29.6	55.5	30.3	28.3	37.8	.75
	1 p.m. 3 p.m.	171.2	57.2	33.4	59.7	34.9	30.4	40.0	.76
	3 p.m. 5 p.m.	196.4	51.7	26.3	57.2	29.1	29.1	36.2	.81
	5 p.m. 7 p.m.	196.2	59.5	30.4	60.1	30.6	30.6	41.7	.73
	7 p.m. 9 p.m.	192.1	56.2	29.3	60.0	31.2	30.5	39.4	.78
	9 p.m. 11 p.m.	170.1	52.8	31.1	53.5	31.5	27.2	37.0	.74
	11 p.m. 1 a.m.	176.5	49.3	27.9	51.4	29.1	26.2	34.5	.76
	1 a.m. 3 a.m.	148.1	48.9	33.0	49.1	33.2	25.0	34.2	.73
	3 a.m. 5 a.m.	152.9	37.0	24.2	41.6	27.2	21.2	25.9	.82
	5 a.m. 7 a.m.	120.1	35.4	29.5	41.1	34.2	20.9	24.8	.84
	Total.......	2103.8	622.4	29.6	652.9	31.0	332.4	435.7	.76
Dec. 21–22.	7 a.m. to 9 a.m.	223.5	70.4	31.5	66.5	29.7	33.8	49.3	.69
	9 a.m. 11 a.m.	175.2	54.2	30.9	58.0	23.1	29.6	37.9	.78
	11 a.m. 1 p.m.	179.3	56.5	31.5	58.9	32.9	30.0	39.6	.76
	1 p.m. 3 p.m.	196.4	53.6	27.3	57.3	29.2	29.2	37.6	.78
	3 p.m. 5 p.m.	206.9	84.2	40.7	65.4	31.6	33.3	58.9	.57
	5 p.m. 7 p.m.	223.3	59.1	26.5	65.3	29.2	33.2	41.4	.80
	7 p.m. 9 p.m.	189.9	62.6	33.0	62.9	33.2	32.1	43.8	.73
	9 p.m. 11 p.m.	183.5	59.2	32.3	63.6	34.7	32.4	41.4	.78
	11 p.m. 1 a.m.	193.9	53.5	27.6	54.9	28.3	27.9	37.4	.75
	1 a.m. 3 a.m.	155.1	35.3	22.8	45.6	29.4	23.2	24.7	.94
	3 a.m. 5 a.m.	142.4	41.4	29.1	44.6	31.3	22.7	29.0	.78
	5 a.m. 7 a.m.	154.1	41.2	26.8	42.6	27.6	21.7	28.9	.75
	Total.......	2223.5	671.2	30.2	685.6	30.8	349.1	469.9	.74
Dec. 22–23.	7 a.m. to 9 a.m.	207.8	74.0	35.6	72.5	34.9	36.9	51.8	.71
	9 a.m. 11 a.m.	198.3	58.0	29.2	63.3	31.4	32.2	40.6	.80
	11 a.m. 1 p.m.	198.8	60.2	30.3	66.9	33.7	34.1	42.1	.81
	1 p.m. 3 p.m.	217.4	56.4	25.9	63.8	29.4	32.5	39.5	.82
	3 p.m. 5 p.m.	198.2	62.2	31.4	63.3	31.9	32.2	43.6	.74
	5 p.m. 7 p.m.	214.9	72.5	33.7	73.4	34.2	37.4	50.7	.74
	7 p.m. 9 p.m.	248.6	67.9	27.3	72.6	29.2	37.0	47.5	.78
	9 p.m. 11 p.m.	200.9	63.9	31.8	66.8	33.3	34.0	44.7	.76
	11 p.m. 1 a.m.	209.5	62.9	30.0	64.3	30.7	32.7	44.0	.74
	1 a.m. 3 a.m.	187.2	48.2	25.8	57.0	30.5	29.0	33.8	.86
	3 a.m. 5 a.m.	222.0	62.9	28.3	59.9	27.0	30.5	44.0	.69
	5 a.m. 7 a.m.	153.0	43.8	28.7	53.6	35.1	27.3	30.7	.89
	Total.......	2456.6	732.9	29.8	777.4	31.6	395.8	513.0	.77

Analysis of food and feces.—The feces for the whole experimental period were mixed, sampled, and analyzed. Determinations of the water, fat, ash, nitrogen, carbon, hydrogen in organic matter, and heat of combustion of food were made on weighed portions of fresh material. Analyses of the composite sample of feces were made after the material had been partially dried. Protein was computed from the nitrogen by means of the factor 6.25, and the carbohydrates were estimated by difference.[a] The percentage composition of the food and also of the feces is given in table 55.

Weight, composition, and heat of combustion of food and feces.—From the weight, percentage composition, and heat of combustion per gram of food can be found the total amounts of water, elements and compounds, as well as the

TABLE 55.—*Percentage composition of food and feces—Metabolism experiment No. 70.*

Laboratory number.	Date.	Kind of material.	(a) Water.	(b) Protein.	(c) Fat.	(d) Carbohydrates.	(e) Ash.	(f) Nitrogen.	(g) Carbon.	(h) Hydrogen.	(i) Heat of combustion per gram.
	1904.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cals.*
3806	Dec. 20–21..	Milk.....	79.14	3.00	12.63	4.59	0.64	0.48	12.86	2.00	1.525
3807	Dec. 20–21 and 21–22..	...do.....	78.46	3.00	13.56	4.35	0.63	0.48	13.50	2.10	1.598
3808	Dec. 22–23..	...do.....	78.50	3.06	13.41	4.40	0.63	0.49	13.37	2.05	1.593
3773	Dec. 20–23..	Plasmon..	9.80	74.50	0.15	6.88	8.67	11.92	44.21	6.14	4.829
3809	Dec. 20–23..	Feces....	66.39	3.71	23.57	....	[1]6.33	0.59	19.75	3.13	2.447

[1] Ash by difference. See note below.

potential energy, i. e., heat of combustion. Similar computations can be made for the feces. The results for both food and feces are given in table 56.

The total quantity of protein in the food furnished per day ranged from 53.31 to 53.76 grams, while the energy varied from 2569 to 2585 calories. An inspection of the total amounts of material in the diet shows that the amount of food was practically the same for all three days.

The feces were characterized by an abnormally high fat content. The significance of this feature will receive special discussion later.

Elements and materials absorbed from food.—This experiment continued for 3 days, but no feces were passed until the third day, when 119.2 grams were separated and dried for analysis. After the subject came out of the respiration chamber the feces were saved until the appearance of the lampblack taken with the first meal after he left the chamber, when the usual

[a] For special discussion of the analysis of the feces belonging to this experiment, see Analyses of Feces, Experiments with Food, Part 3, of this report.

separation between the colored and uncolored portions of the feces was made. The total weight of fresh feces assumed as resulting from the food consumed during the 3 days of the experiment was 182.9 grams.

Although these feces were not passed in 3 equal daily amounts, it is here assumed, as is customary in experiments of this nature, that the total feces should be apportioned equally among the 3 days of the experiment. Such an apportionment is especially fitting in this particular experiment, because

TABLE 56.—*Weight, composition, and heat of combustion of food and feces—Metabolism experiment No. 70.*

Laboratory number.	Date and kind of material.	(a) Weight.	(b) Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(j) Oxygen (by difference).	(k) Heat of combustion.
	1904. FOOD.											
	Dec. 20-21.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3806	Milk.......	1320.10	1044.73	39.60	166.73	60.59	8.45	6.34	169.76	26.40	64.42	2013
3807	Milk.......	332.80	261.11	9.98	45.13	14.48	2.10	1.60	44.93	6.99	16.07	532
3773	Plasmon ...	5.00	0.49	3.73	0.01	.34	.43	.60	2.21	0.31	0.96	24
	Total for day.	1657.90	1306.33	53.31	211.87	75.41	10.98	8.54	216.90	33.70	81.45	2569
	Dec. 21-22.											
3807	Milk.......	1593.30	1250.10	47.80	216.05	69.31	10.04	7.65	215.10	33.46	76.95	2546
3773	Plasmon ...	8.00	0.79	5.96	.01	.55	.69	.95	3.54	0.49	1.54	39
	Total for day.	1601.30	1250.89	53.76	216.06	69.86	10.73	8.60	218.64	33.95	78.49	2585
	Dec. 22-23.											
3808	Milk.......	1598.30	1254.67	48.91	214.32	70.33	10.07	7.83	213.69	32.77	79.27	2546
3773	Plasmon...	6.23	0.61	4.64	.01	.43	.54	.74	2.75	0.38	1.21	30
	Total for day.	1604.53	1255.28	53.55	214.33	70.76	10.61	8.57	216.44	33.15	80.48	2576
	FECES.											
3809	Total, 3 days.	182.90	121.43	6.79	43.10	....	[1]11.58	1.08	36.12	5.72	6.97	448
	Av. per day.	60.97	40.48	2.26	14.37	....	[1]3.86	0.36	12.04	1.91	2.32	149

[1] Ash by difference. See footnote p. 96.

the kinds of food are the same and the amounts are practically the same for each of the 3 days.

Proximate and ultimate analyses of the food and feces furnish data regarding the amounts in each of water, fat, carbohydrates, ash, nitrogen (protein), carbon, and hydrogen. If it be assumed, then, that the feces represent the material of unabsorbed food, the actual amounts absorbed by the body from the food of each day, determined either in terms of the compounds, protein, fat, carbohydrates, and water, or in terms of chemical elements, may be found by deducting the weights of the elements or compounds in the feces from the weights of corresponding elements or compounds in the food. It is customary to consider the material absorbed from the food in terms of protein, fat, and

carbohydrates, but it seems reasonable to believe that food protein, food fat, and food carbohydrate before being katabolized are first converted into body protein, body fat, and body carbohydrate. For this reason, the chemical elements determined in the absorbed food are combined into body protein, body fat, and body carbohydrate by means of the formulæ given on page 38. In brief, it may be said that the elements of the absorbed food are transposed to terms of body material. Though it is practically the same as has been explained on page 37, an example of the method of performing the transposition,

TABLE 57.—*Illustrative table showing computations of elements and materials absorbed from food—Metabolism experiment No. 70—First day, December 20, 1904.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Food and drink:						
Solids in food...	351.57	8.54	216.90	33.70	81.45	10.98
Water in food...	1306.33	....	....	146.18	1160.15	....
Water in drink..	139.00	....	....	15.55	123.45	....
Total.........	1796.90	8.54	216.90	195.43	1365.05	10.98
Feces:						
Solids..........	20.49	0.36	12.04	1.91	2.32	3.86
Water..........	40.48	....	....	4.53	35.95	....
Total.........	60.97	0.36	12.04	6.44	38.27	3.86
Absorbed..........	1735.93	8.18	204.86	188.99	1326.78	7.12
Protein[1]..........	49.08	8.18	25.91	3.44	10.80	0.75
Fat[1]..............	192.65	....	146.61	22.73	23.31	....
Glycogen[1].........	73.10	....	32.46	4.53	36.11	....
Water.............	1414.73	....	....	158.31	1256.42	....
Ash...............	6.37[2]	....	....	....	....	6.37[2]
Total.........	1735.93	8.18	204.98	189.01	1326.64	7.12

[1] In terms of body material. [2] Ash of protein deducted.

together with the mathematical check upon the accuracy of the computations, is shown in table 57.

On the first day of the experiment according to these computations there were absorbed from the food 8.18 grams of nitrogen, 204.86 grams of carbon, 188.99 grams of hydrogen, 1326.78 grams of oxygen, and 7.12 grams of ash. From the weights of elements absorbed and by means of the formulæ given on page 38 the corresponding weights of body protein, fat, and carbohydrates formed from the elements absorbed were next computed.

The record of the amount of food absorbed and the amount of each element (ash being treated as an element) contained therein is given in table 58, while table 59 repeats the quantity of each element, and shows the amounts of protein, fat, and carbohydrates derived from these elements in terms of body materials.

The quantity of water computed as absorbed from the food on the first day of this experiment is 1414.73 grams. (See column *e* of table 59.) The water of food (obtained by actual determination) and the drinking-water together

TABLE 58.—*Elements absorbed from food—Metabolism experiment No. 70.*

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
First day, Dec. 20, 1904.						
Food and drink:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Solids in food	351.57	8.54	216.90	33.70	81.45	10.98
Water in food	1306.33	....	....	146.18	1160.15	....
Water in drink	139.00	....	....	15.55	123.45	....
Total	1796.90	8.54	216.90	195.43	1365.05	10.98
Feces:						
Solids	20.49	0.36	12.04	1.91	2.32	3.86
Water	40.48	....	....	4.53	35.95	....
Total	60.97	0.36	12.04	6.44	38.27	3.86
Absorbed	1735.93	8.18	204.86	188.99	1326.78	7.12
Second day, Dec. 21, 1904.						
Food and drink:						
Solids in food	350.41	8.60	218.64	33.95	78.49	10.73
Water in food	1250.89	....	....	139.97	1110.92	....
Water in drink	311.00	....	....	34.80	276.20	....
Total	1912.30	8.60	218.64	208.72	1465.61	10.73
Feces:						
Solids	20.49	0.36	12.04	1.91	2.32	3.86
Water	40.48	....	....	4.53	35.95	....
Total	60.97	0.36	12.04	6.44	38.27	3.86
Absorbed	1851.33	8.24	206.60	202.28	1427.34	6.87
Third day, Dec. 22, 1904.						
Food and drink:						
Solids in food	349.25	8.57	216.44	33.15	80.48	10.61
Water in food	1255.28	....	....	140.47	1114.81	....
Water in drink	344.00	....	....	38.49	305.51	....
Total	1948.53	8.57	216.44	212.11	1500.80	10.61
Feces:						
Solids	20.49	0.36	12.04	1.91	2.32	3.86
Water	40.48	....	....	4.53	35.95	....
Total	60.97	0.36	12.04	6.44	38.27	3.86
Absorbed	1887.56	8.21	204.40	205.67	1462.53	6.75

equal 1445.33 grams, while the water of feces actually determined by drying was 40.48 grams. The difference between these two values, 1404.85 grams, according to the common methods of computation, represents the quantity of water absorbed from the food and drink. From the results obtained by means of the formulæ, it appears that the amount of water absorbed from the

food as found by computation is greater by 9.88 grams than the amount absorbed as found by the direct determination of water in the food, drink, and feces.

A possible explanation for this discrepancy is found when it is considered that by the computations, food protein, fat, and carbohydrates are converted to body protein, fat, and glycogen and in this conversion a portion of the organic hydrogen is oxidized to form water. For example, in table 57, it appears that on December 20, 1904, there were 33.70 grams of organic hydrogen in the solids of the food. In the feces, there were 1.91 grams; that is, there were 31.79 grams of organic hydrogen absorbed. In the same table it is seen that there are only 30.70 grams of organic hydrogen in the quantities of protein, fat, and glycogen in terms of body material computed as having

TABLE 59.—*Elements and materials absorbed from food—Metabolism experiment No. 70.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.[1]	(g) Fat.[1]	(h) Carbohydrates.[1]	(i) Ash.
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 20–21....	8.18	204.86	188.99	1326.78	1414.73	49.08	192.65	73.10	7.12
Dec. 21–22....	8.24	206.60	202.28	1427.34	1530.71	49.44	198.55	66.52	6.87
Dec. 22–23....	8.21	204.40	205.67	1462.53	1564.80	49.26	188.50	79.00	6.75
Total, 3 days.	24.63	615.86	596.94	4216.65	4510.24	147.78	579.70	218.62	20.74

[1] In terms of body material.

been absorbed from the food. Of the 31.79 grams absorbed, therefore, 1.09 grams do not appear as organic hydrogen of the compounds absorbed but have been excreted in the form of water. Hence, in this process of converting food elements to body compounds, there has been an oxidation of a small quantity of organic hydrogen, corresponding to 9.74 grams of water. This explains mathematically the discrepancy noted above between the water in food and drink, less that of feces and the water computed as absorbed.[34]

While the mathematical verification of this transformation of organic hydrogen to water in the changing of food materials to body materials is evident, it does not necessarily follow that such transformation actually occurs in the identical manner here described. Furthermore, the energy of the material absorbed from the food when computed by use of the factors for body protein, body fat, and body glycogen is practically the same as the energy of the food less feces actually determined by the bomb calorimeter (see table 60), and so it appears that no energy transformation occurred

[34] The slight difference between 9.88 and 9.74 is due to the dropping of decimals in the calculation.

comparable to that which would be expected to arise from the oxidation of 1.09 grams of organic hydrogen. It is more than likely that the somewhat higher values for the heat of combustion per gram of body protein, fat, and glycogen result from a rearrangement of the molecules of the corresponding compounds of the food, either by cleavage or condensation in such a manner that there is no loss of energy resulting from the transformation.

While any attempt to set forth mathematically, as is here done, the transformations by the body of the elements of food into body materials must, in

TABLE 60.—*Amounts of ingredients of food absorbed, and corresponding amounts of body materials—Metabolism experiment No. 70.*

	(a) Food.	(b) Feces.	(c) Absorbed (a—b).	(d) Body material.
Dec. 20–21, 1904:				
Protein....................grams......	53.31	2.26	51.05	49.08
Fat..........................do........	211.87	14.37	197.50	192.65
Carbohydrates................do........	75.41	....	75.41	73.10
Ash..........................do........	10.98	3.86	7.12	7.12
Energy..................calories......	2569	149	2420	2421
Dec. 21–22, 1904:				
Protein....................grams......	53.76	2.26	51.50	49.44
Fat..........................do........	216.06	14.37	201.69	198.55
Carbohydrates................do........	69.86	....	69.86	66.52
Ash..........................do........	10.73	3.86	6.87	6.87
Energy..................calories......	2585	149	2436	2452
Dec. 22–23, 1904:				
Protein....................grams......	53.55	2.26	51.29	49.26
Fat..........................do........	214.33	14.37	199.96	188.50
Carbohydrates................do........	70.76	....	70.76	79.00
Ash..........................do........	10.61	3.86	6.75	6.75
Energy..................calories......	2576	149	2427	2407

the present state of our knowledge of physiological chemistry, be regarded as distinctly speculative, for the purposes of this discussion, the mathematical verification and explanation of the apparent discrepancy are of interest.

Amounts of ingredients of food absorbed and corresponding amounts of body materials.—Of special interest in this connection is a comparison between the amounts of ingredients of food absorbed as determined by the usual method of deducting the quantities of protein, fats, and carbohydrates in the feces from the corresponding amounts in the food, and the quantities of body material computed in the foregoing calculations to have been absorbed. This comparison is shown in table 60. For convenience, the amounts of protein, fat, carbohydrates, and ash in the food and feces are repeated in columns *a* and *b* from table 56. The nutrients and ash absorbed, in terms of food

nutrients, are shown as the difference between columns *a* and *b* in column *c*. Column *d* repeats the nutrients and ash in terms of body material from table 59.

The agreement between the two sets of results shown in the table is quite striking and the energy values are also singularly alike. The comparison, however, is not as significant as it may at first sight seem, since it practically is no more than a proof of the accuracy of the elementary analyses as compared with the proximate analyses. Of the proximate analyses, that of protein rests upon the same basis, namely, the determination of the element nitrogen in both methods of calculation. The whole comparison (columns *c* and *d*, table 60) is, however, of value in indicating the probable accuracy of the different factors used in computing the quantities of body material and their heat of combustion.

TABLE 61.—*Amounts of protein, fat, and glycogen absorbed*[1] *from food and energy of each*[2]*—Metabolism experiment No. 70.*

Date.	Protein.		Fat.		Glycogen.		(*g*) Total energy (*b*+*d*+*f*).
	(*a*) Amount.	(*b*) Energy.	(*c*) Amount.	(*d*) Energy.	(*e*) Amount.	(*f*) Energy.	
1904.	*Grams.*	*Calories.*	*Grams.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Dec. 20–21......	49.08	277	192.65	1838	73.10	306	2421
Dec. 21–22......	49.44	279	198.55	1894	66.52	279	2452
Dec. 22–23......	49.26	278	188.50	1798	79.00	331	2407

[1] In terms of body material.
[2] Factors for heat of combustion per gram of protein, 5.65 calories; of fat, 9.54 calories; of glycogen, 4.19 calories.

Energy of material absorbed from the food.—As has been pointed out above, the food absorbed is considered as body material. The energy of the materials thus absorbed is readily computed by use of the heats of combustion given on page 50. The results are given in table 61.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

The ingestion of food complicates somewhat the striking of the balance of income and outgo for comparison with the actual changes in body-weight. The data for this experiment are given in table 62. The income here consists of food, water consumed, and oxygen, and the outgo of urine, feces, carbon dioxide, and water of respiration and perspiration. The agreement between the losses of body material and the actual loss in body-weight is thoroughly satisfactory for the first two days; a very considerable discrepancy appears in the comparison for the last day.

In striking such a balance as appears in this table, it was necessary, however, to take account of the actual weight of feces passed regardless of

whether they result from food eaten during the experiment. In this and subsequent food experiments, the weight of the feces passed during the experiment was included in the outgo. In the fasting experiments, however, the feces were neglected entirely in the outgo and their weight was deducted from the loss of body-weight. (See explanation on page 120.) The apparent inconsistency between the methods followed in the fasting and food experiments due to this procedure arises from the fact that it was hoped that more definite information would be obtained as the experiments progressed regarding the relation of the feces in the fasting experiments, and hence in the latter experiments they were withheld from the computations.

TABLE 62.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 70.*

	Dec. 20-21.	Dec. 21-22.	Dec. 22-23.	Total for 3 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Food	1657.90	1601.30	1604.53	4863.73	1621.24
(*b*) Water consumed	1390.00	311.00	344.00	794.00	264.67
(*c*) Oxygen	622.40	671.25	732.89	2026.54	675.51
(*d*) Total $(a+b+c)$	2419.30	2583.55	2681.42	7684.27	2561.42
Outgo:					
(*e*) Urine[1]	1045.80	1056.80	623.30	2725.90	908.63
(*f*) Feces	....	....	119.20	119.20	39.73
(*g*) Carbon dioxide	652.86	6856.3	777.43	2115.92	705.31
(*h*) Water of respiration and perspiration	840.30	1002.78	1059.07	2902.15	967.39
(*i*) Total $(e+f+g+h)$	2538.96	2745.21	2579.00	7863.17	2621.06
(*j*) Gain (+) or loss (−) of body material $(d-i)$	−119.66	−161.66	+102.42	−178.90	−59.64
(*k*) Gain (+) or loss (−) of body-weight	−111.00	−188.00	+ 27.00	−272.00	−90.67

[1] The data of this item should not be confounded with urine data in other tables. (See explanation, p. 66.)

BALANCE OF INTAKE AND OUTPUT.

A consideration of the extent to which the food and drink supplied material for the metabolic processes is possible by comparing the balance of intake and output of the body. The intake and output are shown for convenience of discussion and tabulation in two tables, No. 63, recording the intake and output of water, and No. 64, that of protein, fat, carbohydrates, ash, and energy. In the latter table the gains and losses of each compound are shown, as well as the amounts absorbed and katabolized.

Balance of water.—As has been stated above, table 63 shows the distribution of intake and output of water in the experiment under discussion. Although food was eaten during this experiment, the table differs from previous ones only in that column *a* includes water of feces as well as urine, and column *e*

includes water of food as well as water of drink. In all other respects, the table is identical with preceding ones of this type.

The income of water consists of the water in food and drink. The total outgo of water is the sum of the amounts in the urine, respiration and perspiration, and feces. On the third day, for example (the only day on which feces were passed), there was an intake of water consisting of 1255.28 grams in the food (see table 56) and 344.00 grams of drinking-water (see table 45). On that day there were eliminated 586.16 grams of water in the urine (see table 47), 1059.07 grams of water of respiration and perspiration, 79.1 grams of water in the feces (see footnote, table 63), making the total elimination for the day 1724.33 grams.

TABLE 63.—*Distribution of intake and outgo of water—Metabolism experiment No. 70.*

Date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c—d).
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.	(e) Intake in food and drink.	(f) Loss of preformed water (d—e).	
1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Dec. 20–21.....	991.4	840.3	1831.7	1605.6	1445.3	160.3	226.1
Dec. 21–22.....	1007.0	1002.8	2009.8	1765.5	1561.9	203.6	244.3
Dec. 22–23.....	[1]665.2	1059.1	1724.3	[1]1449.7	1599.3	[2]—149.6	274.6
Total, 3 days.	2663.6	2902.2	5565.8	4820.8	4606.5	214.3	745.0
Av. per day..	887.9	967.4	1855.3	1607.0	1535.5	71.5	248.3

[1] Includes 79.1 grams water of feces passed on this day. In obtaining this amount it is assumed that water existed in the feces passed on this day in the same proportion that it did in the total feces of the experiment.

[2] Gain.

These figures for the intake and outgo indicate an apparent loss to the body of 125.05 grams of water. The preformed water, however, alone represents the actual gain or loss of water to the body, the water of oxidation of organic hydrogen (column *g*, table 63) not being taken into the body as water. On this particular day the body gained 149.57 grams of preformed water (column *f*, table 63).

Nutrients, ash, and energy.—The balances for the materials and energy indicated under this head are shown in table 64.

Protein.—On comparing the protein katabolized (table 51) with the amounts of protein computed in terms of body protein as having been absorbed from the food a noticeable loss in protein is observed not only on the first but also on the two remaining days of the experiment. The average loss was 16.8 grams. The fact that there is a loss on all three days indicates that the food consumed

did not furnish enough protein to supply the demands of the body under the conditions prevailing during the experiment.

Fat.—The amounts of body fat actually katabolized (obtained from column *g* of table 51) are recorded in line *e* of table 64, and the amount of fat in terms of body fat computed to have been absorbed from the food is recorded in line *d*. There was a marked gain of fat on the first day following the fast,

TABLE 64.—*Balance of intake and output of nutrients, ash, and energy—Metabolism experiment No. 70.*

	Dec. 20-21.	Dec. 21-22.	Dec. 22-23.	Total for 3 days.	Average per day.
Body protein:					
(*a*) Computed from elements absorbed from food....gms..	49.08	49.44	49.26	147.78	49.26
(*b*) Katabolized....... ......do...	78.24	59.04	60.90	198.18	66.06
(*c*) Gain (+) or loss (−) to body (*a*−*b*)................do...	−29.16	− 9.60	−11.64	−50.40	−16.80
Body fat:					
(*d*) Computed from elements absorbed from food....do...	192.65	198.55	188.50	579.70	193.23
(*e*) Katabolized..............do...	158.59	193.87	188.90	541.36	180.45
(*f*) Gain (+) or loss (−) to body (*d*−*e*)................do...	+34.06	+ 4.68	− .40	+38.34	+12.78
Body carbohydrates:					
(*g*) Computed from elements absorbed from food....do...	73.10	66.52	79.00	218.62	72.87
(*h*) Katabolized..............do...	56.46	35.95	99.90	192.31	64.10
(*i*) Gain (+) or loss (−) to body (*g*−*h*)................do...	+16.64	+30.57	−20.90	+26.31	+ 8.77
Ash:					
(*j*) In food absorbed.........do...	7.12	6.87	6.75	20.74	6.91
(*k*) Eliminated in urine.......do...	4.54	6.36	8.93	19.83	6.61
(*l*) Gain (+) or loss (−) to body (*j*−*k*)................do...	+ 2.58	+ .51	− 2.18	+ .91	+ .30
Energy:					
(*m*) Of absorbed food (determined)...............cals..	2420	2436	2427	7283	2428
(*n*) Heat production plus potential energy of urine..do..	2207	2305	2548	7060	2353
(*o*) Gain (+) or loss (−) to body (*m*−*n*)........ ....do.	+ 213	+ 131	− 121	+ 223	+ 74

a slight gain on the second, and an insignificant loss on the third day. For the three days there was an average gain of 12.78 grams of fat, showing that on the average the diet supplied a little more than was actually needed and thus the body was enabled to store fat.

Carbohydrates.—The amounts of body carbohydrate or glycogen katabolized each day recorded in line *h* are taken from the data in table 51, while in line *g* the amounts of body carbohydrate computed from the elements absorbed in the food (see table 61) are recorded. There was a gain of carbohydrates on the first two days of the experiment, while on the third day there was a loss.

Ash.—While the ash eliminated in the urine steadily increased from day to day as is seen from results recorded in line *k* of the table, the ash of the food remained practically constant. Consequently, there was a gain on the first day, nearly ash equilibrium on the second day, while there was a marked loss on the third day. On the average the body was practically in ash equilibrium.

Energy.—The object of the balances shown in table 64 is to indicate in how far the losses from the body were compensated by the food ingested and hence the balance which takes into account the energy of these nutrients can also be obtained. Such comparison is shown in the last three lines of the table. In line *m* is given the energy of food absorbed, i. e., the difference between the energy of food and feces as determined by the bomb calorimeter, while line *n* shows the total heat production plus the potential energy of the urine (obtained from columns *b* and *g* of table 53). The differences recorded in line *o* show that on the first day there was a gain of 213 calories of potential energy to the body, on the second a gain of 131 calories and on the last day a loss of 121 calories. On the whole, therefore, the diet supplied somewhat more energy than was actually given off by the body.

The results obtained in line *o* require special comment. The figures as given in the table represent the gain or loss to the body of potential energy, not the actual amount of energy which would be gained or lost if the energy of the absorbed food were liberated in the body. Furthermore, the results obtained in line *o* can not be obtained by multiplying the gain or loss of the nutrients shown in lines *c*, *f*, and *i* by their respective heats of combustion. If, for example, such computations be made the first day of the experiment, the result obtained would be 230 instead of 213 as shown in the table. Thus $(-29.16 \times 5.65) + (34.06 \times 9.54) + (16.64 \times 4.19) = 230$. The discrepancy between 213 and 230 may be avoided by using in line *n* in place of 2207 calories, 2192 calories, the total energy of the material oxidized in the body plus the potential energy of the urine, and using in line *m* 2421 calories (energy of absorbed food computed by means of factors for heat of combustion, line *g*, table 62) in place of 2420 calories. The case is exactly the same for the remaining days of the experiment. For showing the gain or loss to the body of potential energy, however, the figures in line *o* should remain unchanged.

METABOLISM EXPERIMENT NO. 71.

The results from the 3- and 4-day fasts previously reported were of so much value, even though made with subjects unaccustomed to fasting, that still longer experiments with an experienced faster seemed desirable. Accordingly, in the belief that the experimental conditions would be still more nearly normal, a series of experiments was planned with a subject who had fasted in private a number of times and hence was thoroughly accustomed to the sensations of hunger.

A young man, a professional masseur, who maintained that he had on several occasions made fasts of ten days' duration, was secured as the subject of experiments Nos. 71 to 77, inclusive. On his arrival in Middletown the methods of experimenting were explained to him in detail, and in order to accustom him to life within the calorimeter chamber, he remained in the chamber for a few hours on several days prior to the first experiment. Every precaution was taken to insure a normal mental as well as physical condition during the experiment, but that his mental state, in spite of all precautions, was one of apprehension throughout the experiment, is evident from the extracts from his diary recorded later. Entire unfamiliarity with scientific methods of research, an inadequate schooling, and an exceedingly nervous temperament resulted in a condition of nervous excitement during the first experiment that seemed to preclude further experimenting with this subject. Increased familiarity with the apparatus and methods, life in the laboratory, and attendance on several college classes so increased his confidence in the nature of the experiments, however, that the series planned for was ultimately carried out. But even then many changes in method had to be made and much desired data could not be obtained.

The subject, S. A. B., entered the chamber in the early evening of January 6, 1905. The preliminary analyses of the respiratory products began at 1 a. m., January 7, and the experiment began 6 hours later. The day was subdivided into experimental periods of 2 hours' duration, the heat, carbon dioxide, oxygen, and water-vapor being determined accordingly.

The body measurements of the subject, taken about 2 weeks after the end of the fast, are given below:

Measurements of S. A. B.—Date, Jan. 25, 1905. Age, 23 years.

Weight ....kilograms..	62.1	Girth of—	
Height, standing ...centimeters..	165.8	Lower chest—	
Girth of—		Repose ....centimeters..	77.7
Neck ....do....	36	After expiration.......do....	71.3
Upper chest—		After inspiration......do....	81.7
Repose ....do....	90.5	Waist ....do....	69.8
After expiration.......do....	85	Right upper arm........do....	27.9
After inspiration......do....	96.5	flexed ....do....	31.2

Girth of—	
Right forearm, contracted, centimeters..	26.6
Left upper arm..........do....	26.4
flexed ....do....	28.9
Left forearm, contracted..do....	26
Right thigh ....do....	48.5
Right calf ....do....	31.3
Left thigh ....do....	47
Left calf ....do....	32
Depth of—	
Chest ....centimeters..	22.7
Abdomen ....do....	16.9
Breadth of—	
Shoulders ....do....	38.1
Chest ....do....	25.7
Waist ....do....	24.8
Hips ....do....	31.6

Notes from diary.—Throughout this experiment, the subject made a large number of notes concerning his physical and mental condition. These are of interest in connection with the statements previously made. The notes as here recorded have been shortened considerably, and a large number of observations on the condition of the tongue have been eliminated. The condensed form of the diary is here given.

Notes from diary.

Jan. 7, 1905:

7^h20^m a. m. Passed a very restless night; dozed off about 12^h30^m and awoke with a nightmare. Had very horrible forebodings. Felt as if I were stifling; know I was a little nervous. Have a warm sweat on my forehead and my face is flushed. Drank some water during night; would have risen at about 6^h30^m a. m. to urinate had it not been contrary to instructions. My nostrils feel parched.

10^h30^m a. m. My eyes feel blurred and dim. The air in the calorimeter seems much better than it did at night; it seems fresher and cooler. My tongue is coated and I have a sour taste in my mouth; do not feel as nervous as I did this morning. Have belched wind all the morning, due, perhaps, to the fermentation of the beans I ate last night at 7^h30^m.[a]

1^h30^m p. m. My mouth feels very dry with unpleasant taste.

5^h30^m p. m. Some of my nervousness has passed. Lips are parched, and I have a slight headache. At times there appeared to be a noxious odor in here, but it quickly passed away and the air became a trifle cooler. There are eructations from stomach occasionally, which cause a sour taste in my mouth; no discomfort otherwise.

7^h45^m p. m. Had a desire to defecate, but I have considerable pain caused by the rectal thermometer, and the pain caused me to cease the effort.

8 p. m. The only discomfort I feel is caused by the rectal thermometer.

9 p. m. Feel very sleepy.

Jan. 8, 1905:

7^h30^m a. m. Have passed a better night. Slept more and had no "danger" forebodings.

8 a. m. Feel faint and weak; my nerves are shaky. This will pass off in a day or so. Tongue coated with a white fur, having a sour taste; face feels flushed.

11^h15^m a. m. Feel weak and relaxed; will lie down.

1 p. m. Feel much better after lying down. Have a slight headache; am not hungry. Irritation in rectum not so painful since rectal thermometer was removed.

5^h30^m p. m. Have been sleeping since 2^h30^m p. m. If I had room I would do some walking. Would prefer fasting outside the calorimeter. My bilious headache goes and comes about every hour or so.

7 p. m. My weakness is passing away, but, Oh, how I long for a walk of from 6 to 10 miles in the open air! There is not much "fun" in reading and sleeping. My mouth feels very dry and I need a considerable amount of water. Still have a sour taste in mouth, and coated tongue; my nerves are a little better. I am commencing to feel dirty, for want of a good shave and warm bath. The atmosphere is not very pleasant in here.

9^h15^m p. m. Feel very sleepy. I lay down and fell asleep and awoke at signal to retire.

[a] Evening meal, Jan. 6, 1905, consisted of baked beans, 2 ham sandwiches, and 1 cup of coffee.

Jan. 8, 1905:

10^h30^m p. m. Sleepy feeling has passed away; only feel weak. My brain is becoming clearer; bad taste in mouth less noticeable. Feel listless.

Jan. 9, 1905:

7^h30^m a. m. Did not sleep as well as the night before, possibly because I slept during the day. Feel very weak, for want of fresh air; during my previous fasts I have taken a walk in the open air whenever I commenced to feel sleepy or weak, and the feeling would soon pass away. My tongue is still coated and have sour taste in my mouth. My colon is filled with fecal matter which I can not pass out.

10^h30^m a. m. Feel very sleepy. My brain is tired; can not think much; feel more like a caged animal than a human being.

1^h30^m p. m. Not uncomfortable but weak; do not feel hungry yet. The air in here is very dry. Much gas is passing out via rectum.

5^h30^m p. m. Have had no headache all day; tongue still coated, but bad taste slowly passing away.

7^h30^m p. m. Am commencing to have a slight headache (bilious); my mind is very much clearer than it was this morning.

Jan. 10, 1905:

7^h30^m a. m. Did not sleep very well last night. Changed my position too often to be comfortable, but did not have any "danger" forebodings as on the first night. Feel very weak but not hungry; tongue coated. I can scrape it off. This morning upon arising my tongue appeared to be swollen and sticking to the roof of my mouth. Eyes look red; am commencing to have a slight headache again. My nerves are very shaky; brain is not clear.

10^h30^m a. m. Feel a little stronger to-day; brain is clearer and nerves are not so shaky. Have better self-control. Feel very dirty; my body is commencing to give off a very disagreeable odor.

1^h30^m p. m. Received some newspapers, and after reading them became more cheerful. It is commencing to become tedious staying in here; being of a nervous temperament I always want to be moving about, changing my position, etc. The drinking-water is beginning to have an ill effect on me. Am commencing to have cramps intermittently in stomach and intestines. The water is also causing the disagreeable taste and coated tongue.

2^h30^m p. m. Have a little nausea and hiccough frequently; my heart is commencing to pain me a little.

4^h30^m p. m. Swallowed some water and hiccoughs commenced again, also heart pain.

5^h30^m p. m. Am commencing to feel weak again; feel all relaxed. Have cramps in my intestines continually now. The water tastes very badly to me; it is bitter and nauseating.

7^h15^m p. m. My head is commencing to ache a little. Have had a desire to defecate all day.

Jan. 11, 1905:

7^h15^m a. m. Did not sleep well; do not believe I slept 1 hour all told. Was not in any discomfort; simply lay down and occasionally changed my position. Did not feel tired on arising. Eyes red.

Pulse.—The records of pulse as taken by the subject are given below.

Experiment No. 71.[1]

Time.	Pulse rate.	Time.	Pulse rate.
Jan 7, 1905, 7^h 30^m a.m.	76	Jan. 9, 1905, 1^h 30^m a.m.[3]	68
9 10 a.m.	74	8 00 a.m.	68
9 20 a.m.	82	10 30 a.m.	64
10 30 a.m.	76	1 30 p.m.	64
1 30 p.m.	75	5 30 p.m.	62
5 30 p.m.	75	8 00 p.m.	62
8 00 p.m.	76	Jan. 10, 1905, 7 30 a.m.	58
Jan. 8, 1905, 8 00 a.m.	78	10 30 a.m.	62
10 30 a.m.	72	1 30 p.m.	62
1 30 p.m.[2]	72	5 30 p.m.	60
5 30 p.m.[2]	72		
8 00 p.m.[2]	68		

[1] Pulse taken while sitting unless otherwise specified. [2] Lying down. [3] Standing.

Routine.—No prescribed program was insisted upon and the subject was permitted to choose the routine which would be most convenient. During other fasts outside the respiration chamber he had been accustomed to do a considerable amount of walking and hence he desired to have the bicycle ergometer placed inside the chamber in order that he might exercise each day. Shortly after 9 o'clock of the first day he mounted the ergometer and rode against resistance at a fairly rapid rate for about 10 minutes. On subsequent days he was disinclined to take even this exercise, hence his muscular activity was greatest on the first day.

Body movements.—A record of body movements compiled from the subject's diary, the record sheet of the food aperture, and observations of the physical observer is given herewith.

Movements of subject.—Duration, 4 days, from Jan. 7, 7 a. m., to Jan. 11, 7 a. m., 1905.

	January 7.
A. M.	
$7^h 00^m$	rise, urinate.
7 04	begin weighing.
7 14	weigh self.
7 18	weigh absorbers.
7 22	finish weighing.
7 24	dress.
7 26	sit, write.
7 28	telephone.
7 30	sit, count pulse.
7 44	food aperture.
7 48	stand, move about.
7 52	comb hair.
7 56	adjust table.
8 02	write.
8 12	drink.
8 14	write.
9 00	telephone.
9 02	write.
9 06	stop writing, drink.
9 12	telephone.
9 14	prepare ergometer.
9 15	count pulse.
9 17	ride.
9 27	stop riding, count pulse.
9 36	close curtain, defecate, urinate.
9 42	sit.
9 44	food aperture.
9 46	sit.
9 48	open curtain.
9 52	sit.
9 54	drink.
10 02	read.
10 30	count pulse.
11 04	fold table.
A. M.	
$11^h 12^m$	rise, food aperture.
11 22	write, stand.
11 48	food aperture.
11 52	write.
P. M.	
$12^h 20^m$	write.
12 28	drink, write.
1 00	urinate.
1 08	rise.
1 10	food aperture.
1 16	sit.
1 30	count pulse.
2 00	rise.
2 02	urinate.
2 08	sit.
2 10	read.
2 30	food aperture.
2 54	stop reading.
3 30	read, stand.
3 40	sit.
3 44	read.
5 02	telephone.
5 08	rise.
5 14	sit, rise, food aperture.
5 16	telephone.
5 24	move about.
5 30	count pulse.
5 38	sit.
5 40	read.
5 48	rise.
5 52	sit, adjust table.
5 56	read.
7 02	urinate.
7 06	stand, read.
7 28	move about.
7 32	food aperture.
7 36	close curtain.
P. M.	
$7^h 45^m$	attempt to defecate.
7 48	open curtain.
7 50	food aperture.
7 52	adjust telephone.
8 00	food aperture, count pulse.
8 04	stand, write.
8 28	sit, read.
9 06	remove table.
9 10	arrange bed.
9 14	lie.
11 00	wake, rise.
11 02	undress.
11 03	urinate.
	January 8.
A. M.	
$7^h 00^m$	rise, urinate.
7 02	fold bed.
7 04	begin weighing.
7 14	finish weighing.
7 16	food aperture.
7 20	sit, write.
7 24	defecate.
7 32	food aperture.
7 34	adjust telephone.
7 48	telephone.
7 52	sit.
7 56	food aperture.
7 58	sit.
8 00	count pulse.
8 02	read.
8 24	telephone.
9 02	telephone.
9 04	food aperture.
9 06	read, stand.
9 14	food aperture.
9 15	take temperature.

Movements of subject.—Continued.

January 8 (cont).

A. M.
9h 16m telephone.
9 18 arrange chair, read.
9 20 telephone.
9 22 food aperture.
9 30 telephone.
9 32 food aperture.
9 34 remove table, sit, read.
10 28 rise.
10 30 urinate, count pulse.
10 32 sit, read.
11 16 rise, walk about.
11 22 food aperture.
11 24 adjust bed.
11 26 lie, read.
11 40 telephone.
P. M.
1h 00m urinate.
1 06 sit.
1 20 count pulse.
1 30 lie, read.
2 10 telephone.
2 12 food aperture.
2 14 lie.
3 02 asleep.
5 28 awake, sit, drink.
5 30 count pulse, lie, write.
5 32 telephone.
5 36 food aperture.
5 38 sit.
5 44 telephone.
5 52 move about.
5 58 sit, read.
6 12 stand.
6 16 telephone.
6 18 sit, read.
7 00 rise, urinate.
7 04 sit, write.
7 20 food aperture.
7 32 lie.
8 00 count pulse.
9 15 asleep.
11 00 rise.
11 02 open bed.
11 04 urinate, undress, retire.

January 9.

A. M.
1h 30m rise, count pulse, write.
7 00 rise, urinate.
7 04 begin weighing.
7 11 finish weighing.
7 22 close curtain.
7 24 defecate.
7 25 food aperture.
7h 36m open curtain.
7 40 sit.
8 00 count pulse.
8 02 adjust table.
8 04 write.
8 08 telephone.
8 12 rise, food aperture.
8 16 sit.
8 18 write.
8 26 drink.
8 34 read.
9 48 rise, sit.
10 00 food aperture.
10 02 rise, move about.
10 06 sit.
10 30 count pulse, write.
10 32 asleep in chair.
11 00 awake.
11 04 stand, telephone.
11 12 rise, move about.
11 18 sit.
11 20 read.
11 46 telephone.
11 48 food aperture.
11 50 sit, read.
P. M.
12h 04m drink.
12 16 food aperture.
12 18 sit, read.
1 00 telephone, rise, urinate, move about.
1 06 food aperture.
1 12 lean on table.
1 30 count pulse, write.
2 10 food aperture.
2 16 sit.
2 30 read.
3 02 rise, move about.
3 04 lean on table.
3 07 food aperture.
3 14 telephone.
3 16 write.
3 40 sit.
3 42 write.
4 18 food aperture.
4 20 drink, sit.
4 26 read.
5 04 rise, move about.
5 08 lean on table.
5 10 telephone.
5 12 write.
5 30 count pulse, write.
5 32 telephone.
6 00 food aperture.
6 16 sit.
7 00 rise, urinate.
7 04 sit, read.
7 30 write.
8 00 food aperture, count pulse.
8h 28m sit.
9 05 food aperture.
9 10 food aperture.
9 48 rise.
9 54 open bed.
10 00 sit.
11 00 close curtain, undress, urinate, retire.

January 10.

A. M.
7h 00m rise, urinate.
7 03 begin weighing.
7 08 finish weighing.
7 10 dress.
7 12 sit.
7 28 food aperture.
7 32 close curtain.
7 40 open curtain.
7 44 sit, write.
8 10 telephone.
8 14 move about.
8 16 read.
8 28 rise.
8 30 sit.
9 00 telephone.
9 04 food aperture.
9 06 telephone.
9 08 food aperture.
9 10 lean on table, read.
9 22 sit, read.
10 06 rise, move about.
10 20 sit.
10 22 food aperture.
10 24 sit, read.
11 28 telephone.
11 36 food aperture.
11 38 telephone.
11 40 stand.
11 44 sit, read.
P. M.
12h 08m telephone.
12 46 rise, sit.
1 02 telephone, rise, urinate, move about.
1 04 sit.
1 30 count pulse.
1 32 lean on table, write.
2 30 write.
3 20 food aperture.
3 22 lean on table, write.
3 40 telephone.
4 02 sit.
4 04 stand.
4 14 move about, drink.
4 22 sit, write.
4 24 read.
5 04 rise, stretch arms.

Movements of subject.—Continued.

January 10 (cont.).

P. M.		P. M.		P. M.	
5h 06m	drink.	7h 00m	rise.	9h 00m	lean on table, read.
5 16	lean on table, write.	7 02	take temperature.	9 12	stand.
5 26	telephone.	7 04	urinate.	9 14	arrange bed.
5 30	count pulse, write.	7 08	food aperture.	9 16	lie.
5 54	move about.	7 10	lean on table, read.	11 00	rise.
5 58	sit, read.	7 12	telephone.	11 02	close curtain, undress, urinate, retire.
		7 15	write.		
		8 08	sit, read.		

Drinking-water.—Drinking-water was furnished from the city supply and the subject drank much larger amounts than any previous subject. The quantities for each day, apportioned as nearly as possible among the different experimental periods, are given in table 65. Great differences in the amount of water consumed daily may be observed. While about 1200 grams were consumed on the first day of the fast, on the second and third days the amount consumed per day averaged more than 2 liters. On these 2 days a considerable

TABLE 65.—*Record of water consumed*[1]—*Metabolism experiment No. 71.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	Total for day.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 7–8.....	202.05	202.05	198.60	198.60	201.55	201.55	....	....	1204.40
Jan. 8–9.....	397.20	393.10	397.20	197.40	197.40	....	195.45	195.45	1973.20
Jan. 9–10....	404.50	389.10	197.20	197.20	391.60	194.80	194.80	343.70	2312.90
Jan. 10–11....	384.60	395.60	194.00	194.00	158.55	158.55	....	....	1485.30

[1] Period during which water was consumed was assumed in some instances.

amount of water was taken between 7 and 11 p. m. On the first and last days no water was consumed after 7 p. m.

URINE.

The urine was collected as usual at the end of each of the 4 periods, but on the first day the subject accidentally mixed the urine of the first and second periods. Determinations were made of the specific gravity, reaction, and nitrogen of the urine for each period. These are recorded in table 66. The quantity of urine voided is nearly proportional to the amount of water drunk, there being on the third day over 2.5 liters passed. Throughout the experiment the specific gravity was low and the reaction acid.

Weight, composition, and heat of combustion of urine.—Aside from the determinations given in table 66 on the samples of urine for the 4 usual periods, each daily composite sample was analyzed. Determinations were made of the water, total solids, ash, nitrogen, carbon, organic hydrogen, phosphorus, sulphur, and heat of combustion. From the percentages thus obtained, the heat of combustion per gram and the weight of urine, the quantities of the various elements and the total heat of combustion are computed. These are recorded

in table 67. As in experiments Nos. 69 and 70 the results were obtained from actual determinations made in duplicate in all cases, and in many cases in triplicate. The phosphorus and sulphur determinations are expressed not only in terms of elements but also as oxides. Both elements were determined by the fusion method.

TABLE 66.—*Determinations in urine per period and per day—Metabolism experiment No. 71.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a+b).	(d) Reaction.	(e) Nitrogen.
1905.		*Grams.*		*c. c.*		*Grams.*
Jan. 7–8....	7 a.m. to 1 p.m. } 1 p.m. 7 p.m. }	985.6	1.0072	979	Slightly acid.	3.29
	7 p.m. 11 p.m.	65.5	1.0153	64	Acid.........	0.77
	11 p.m. 7 a.m.	108.4	1.0215	106	....do........	1.78
	Total..........	1159.5	....	1149	....	5.84
	Total by composite.......	1159.5	1.0089	1149	....	5.82
Jan. 8–9....	7 a.m. to 1 p.m.	830.4	1.0042	827	Acid.........	3.04
	1 p.m. 7 p.m.	550.6	1.0061	547	....do........	2.74
	7 p.m. 11 p.m.	307.5	1.0058	306	....do........	1.94
	11 p.m. 7 a.m.	332.6	1.0101	329	....do........	3.32
	Total..........	2021.1	....	2009	....	11.04
	Total by composite........	2021.1	1.0058	2009	Acid.........	11.02
Jan. 9–10...	7 a.m. to 1 p.m.	753.2	1.0046	750	Acid.........	3.46
	1 p.m. 7 p.m.	608.7	1.0073	605	....do........	3.47
	7 p.m. 11 p.m.	443.8	1.0048	442	....do........	2.10
	11 p.m. 7 a.m.	735.9	1.0054	732	....do........	4.07
	Total..........	2541.6	....	2529	....	13.10
	Total by composite........	2541.6	1.0048	2529	Acid.........	13.16
Jan. 10–11..	7 a.m. to 1 p.m.	644.0	1.0052	640	Acid...	3.36
	1 p.m. 7 p.m.	522.5	1.0067	519	....do........	2.85
	7 p.m. 11 p.m.	105.9	1.0190	104	....do........	1.47
	11 p.m. 7 a.m.	213.4	1.0173	210	....do........	3.06
	Total..........	1485.8	....	1473	....	10.74
	Total by composite.......	1485.8	1.0087	1473	Acid.........	10.67
	Total, 4 days...	7208.0	....	7160	....	40.72

ELIMINATION OF WATER-VAPOR.

The water of respiration and perspiration, together with the amount of water-vapor residual in the chamber at the end of each 2-hour period, is recorded in table 68 (see page 115). The daily amounts of water gained or lost by articles in the chamber are given in the foot-note to the table. This water was apportioned in equal amounts among all the 2-hour periods of the day.

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An inspection of the figures in column *a* shows that the relative humidity in the chamber steadily decreased during the 4 days, thus explaining the continual loss of moisture from the bedding and furniture.

The total water of respiration and perspiration diminished from day to day, amounting to 744.84 grams on the first day and 517.66 grams on the fourth day.

Cutaneous excretion of nitrogenous material.—During this experiment and experiment No. 72 immediately following there was an average elimination of nitrogen of 0.029 gram per day found in the perspiration.

TABLE 67.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 71.*

	Jan. 7-8.	Jan. 8-9.	Jan. 9-10.	Jan. 10-11.	Total for 4 days.
(*a*) Weight................grams..	1159.5	2021.1	2541.6	1485.8	7208.0
(*b*) Water....................do....	1133.99	1984.11	2500.68	1449.25	7068.03
(*c*) Solids (*a*—*b*).............do....	25.51	36.99	40.92	36.55	139.97
(*d*) Ash......................do....	7.65	6.06	5.85	5.94	25.50
(*e*) Organic matter (*c*—*d*).....do....	17.86	30.93	35.07	30.61	114.47
(*f*) Nitrogen.................do....	5.84	11.04	13.10	10.74	40.72
(*g*) Carbon...................do....	5.22	8.29	8.64	7.73	29.88
(*h*) Hydrogen in organic matter, grams.......................	1.16	2.02	2.29	2.08	7.55
(*i*) Oxygen (by difference) in organic matter, $e-(f+g+h)$...grams..	5.64	9.58	11.04	10.06	36.32
(*j*) Phosphorus..............do....	.322	.579	.873	.889	2.663
(*k*) Phosphoric acid by fusion (P_2O_5), grams.......................	.736	1.326	2.000	2.038	6.100
(*l*) Sulphur.................grams..	.519	.711	.758	.670	2.658
(*m*) Sulphur trioxide (SO_3)....do....	1.298	1.774	1.893	1.671	6.636
(*n*) Heat of combustion....calories..	58	91	99	86	334

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

From the analyses of the respiratory gases, the quantities of carbon dioxide and oxygen residual in the chamber at the end of each period are obtained. These are recorded in columns *a* and *c* of table 69. The weights of carbon dioxide exhaled and the amounts of oxygen consumed by the subject are shown in the same table in columns *b* and *d*, respectively.

There are especially noticeable differences in the absolute amounts of carbon dioxide present in the chamber, both from one period to another and from day to day. The residual amounts tend to diminish as the experiment progresses, while on the other hand the amounts of oxygen tend to increase. For instance, the residual oxygen varies from 831.9 liters at 11 a. m., January 7, to 1090.2 liters at the end of the experiment. Corresponding to these wide differences in the amounts of oxygen, there are of course variations in the absolute percentages of oxygen in the air, but as has been shown by Zuntz, Durig, and

others,[26] the respiratory exchange is unaffected by a diminished percentage of oxygen unless that percentage falls below 11. In none of the experiments thus

TABLE 68.—*Record of water of respiration and perspiration—Metabolism experiment No. 71.*

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]	Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905.			1905.		
Jan. 7:	*Grams.*	*Grams.*	Jan. 9–10:	*Grams.*	*Grams.*
Preliminary: 1 a.m.	43.0	....	7 a.m. to 9 a.m.	34.5	52.0
1 a.m. to 3 a.m.	40.6	64.0	9 a.m. 11 a.m.	31.4	51.0
3 a.m. 5 a.m.	37.4	59.7	11 a.m. 1 p.m.	30.1	45.0
5 a.m. 7 a.m.	38.3	62.3	1 p.m. 3 p.m.	28.9	48.7
Total	....	186.0	3 p.m. 5 p.m.	30.2	48.3
Jan. 7–8:			5 p.m. 7 p.m.	29.8	52.1
7 a.m. to 9 a.m.	45.6	81.6	7 p.m. 9 p.m.	30.9	46.9
9 a.m. 11 a.m.	49.5	81.2	9 p.m. 11 p.m.	28.7	48.1
11 a.m. 1 p.m.	43.8	69.9	11 p.m. 1 a.m.	28.6	44.2
1 p.m. 3 p.m.	43.1	64.3	1 a.m. 3 a.m.	27.7	44.7
3 p.m. 5 p.m.	41.3	70.1	3 a.m. 5 a.m.	28.0	43.5
5 p.m. 7 p.m.	42.3	66.7	5 a.m. 7 a.m.	26.8	43.1
7 p.m. 9 p.m.	39.5	70.5	Total	....	567.6
9 p.m. 11 p.m.	38.9	51.1	Jan. 10–11:		
11 p.m. 1 a.m.	33.1	55.3	7 a.m. to 9 a.m.	30.6	51.6
1 a.m. 3 a.m.	33.7	50.7	9 a.m. 11 a.m.	27.5	42.6
3 a.m. 5 a.m.	37.8	33.4	11 a.m. 1 p.m.	27.8	42.5
5 a.m. 7 a.m.	33.9	50.0	1 p.m. 3 p.m.	29.9	43.8
Total	....	744.8	3 p.m. 5 p.m.	28.4	43.3
Jan. 8–9:			5 p.m. 7 p.m.	28.1	48.4
7 a.m. to 9 a.m.	42.4	82.5	7 p.m. 9 p.m.	28.1	42.8
9 a.m. 11 a.m.	39.6	67.9	9 p.m. 11 p.m.	28.5	39.7
11 a.m. 1 p.m.	35.6	54.5	11 p.m. 1 a.m.	26.3	41.6
1 p.m. 3 p.m.	34.0	58.2	1 a.m. 3 a.m.	25.6	43.3
3 p.m. 5 p.m.	31.5	50.5	3 a.m. 5 a.m.	27.4	40.6
5 p.m. 7 p.m.	30.8	55.7	5 a.m. 7 a.m.	28.7	37.5
7 p.m. 9 p.m.	31.1	52.7	Total	....	517.7
9 p.m. 11 p.m.	27.7	49.2			
11 p.m. 1 a.m.	29.9	49.1			
1 a.m. 3 a.m.	27.6	48.9			
3 a.m. 5 a.m.	28.9	44.6			
5 a.m. 7 a.m.	28.7	51.4			
Total	....	665.2			

[1] Allowance has been made for water lost by the absorber, chair, bedding, and miscellaneous articles as follows: Jan. 7-8, 24.45 grams; Jan. 8-9, 53.45 grams; Jan. 9-10, 31.78 grams; Jan. 10-11, 37.01 grams.

far made has the percentage of oxygen remaining in the chamber approached this latter point, and hence the atmosphere breathed by the subjects of these experiments has not influenced the character or amount of the respiratory exchange.

[26] U. S. Dept. Agriculture, Office of Exp. Sta. Bul. 175.

TABLE 69.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 71.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 7.......	1 a. m.............	32.9	....	918.2	....
	1 a. m. to 3 a. m..	28.8	42.7	907.3	35.4
	3 a. m. 5 a. m..	30.6	44.7	887.1	28.9
	5 a. m. 7 a. m..	34.4	51.8	863.9	48.7
	Total...........	....	139.2	....	113.0
Jan. 7-8.....	7 a. m. to 9 a. m..	41.5	86.1	845.9	77.3
	9 a. m. 11 a. m..	56.9	105.2	831.9	71.5
	11 a. m. 1 p. m..	41.0	61.6	843.3	51.6
	1 p. m. 3 p. m..	39.3	53.4	846.9	50.6
	3 p. m. 5 p. m..	33.1	51.3	858.4	45.6
	5 p. m. 7 p. m..	34.5	51.7	861.9	47.9
	7 p. m. 9 p. m..	35.3	60.6	871.0	56.0
	9 p. m. 11 p. m..	24.9	39.1	888.1	36.5
	11 p. m. 1 a. m..	23.2	39.9	892.2	35.0
	1 a. m. 3 a. m..	24.6	41.1	899.6	37.1
	3 a. m. 5 a. m..	35.1	38.5	927.3	40.2
	5 a. m. 7 a. m..	27.7	40.5	948.4	39.8
	Total...........	....	669.0	....	589.1
Jan. 8-9.....	7 a. m. to 9 a. m..	35.1	74.7	942.8	74.1
	9 a. m. 11 a. m..	30.2	54.7	951.4	67.7
	11 a. m. 1 p. m..	30.5	53.3	963.0	46.5
	1 p. m. 3 p. m..	29.0	52.7	971.5	54.7
	3 p. m. 5 p. m..	23.6	39.1	993.0	31.9
	5 p. m. 7 p. m..	24.4	48.5	1003.5	48.4
	7 p. m. 9 p. m..	26.1	50.3	1015.9	52.6
	9 p. m. 11 p. m..	19.9	36.8	1035.7	33.0
	11 p. m. 1 a. m..	21.2	41.2	1054.3	38.3
	1 a. m. 3 a. m..	20.4	39.4	1053.5	39.7
	3 a. m. 5 a. m..	22.7	40.1	1060.4	33.6
	5 a. m. 7 a. m..	21.9	39.4	1070.2	33.6
	Total...........	....	570.2	....	554.1
Jan. 9-10....	7 a. m. to 9 a. m..	34.6	62.7	1070.4	66.5
	9 a. m. 11 a. m..	26.8	44.5	1078.3	44.5
	11 a. m. 1 p. m..	28.2	47.2	1074.8	42.6
	1 p. m. 3 p. m..	28.3	53.2	1078.2	49.7
	3 p. m. 5 p. m..	30.1	51.4	1070.7	50.6
	5 p. m. 7 p. m..	28.7	51.1	1074.6	48.5
	7 p. m. 9 p. m..	29.3	46.2	1069.6	47.5
	9 p. m. 11 p. m..	26.3	57.4	1059.8	56.2
	11 p. m. 1 a. m..	22.0	36.3	1051.9	32.3
	1 a. m. 3 a. m..	19.7	33.5	1049.9	32.1
	3 a. m. 5 a. m..	23.3	37.2	1041.7	36.7
	5 a. m. 7 a. m..	19.5	33.3	1039.6	30.8
	Total...........	....	554.0	....	538.0

TABLE 69.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 10–11...	7 a. m. to 9 a. m..	27.7	56.8	1034.6	55.1
	9 a. m. 11 a. m..	26.9	45.4	1038.0	41.8
	11 a. m. 1 p. m..	29.0	46.5	1037.0	41.4
	1 p. m. 3 p. m..	29.9	48.1	1038.8	53.5
	3 p. m. 5 p. m..	28.2	47.1	1048.7	46.5
	5 p. m. 7 p. m..	23.0	44.3	1062.4	42.9
	7 p. m. 9 p. m..	26.9	46.6	1066.0	45.1
	9 p. m. 11 p. m..	20.0	37.2	1074.4	36.0
	11 p. m. 1 a. m..	20.3	35.4	1074.2	32.2
	1 a. m. 3 a. m..	18.9	33.2	1080.4	36.9
	3 a. m. 5 a. m..	19.5	31.8	1083.1	34.1
	5 a. m. 7 a. m..	19.0	35.7	1090.2	27.2
	Total...........	....	508.1	....	492.7

That the amount of carbon dioxide eliminated is greatest on the first day is largely due to the extra muscular exercise taken during the second period. During this period it is seen that there were 105.2 grams of carbon dioxide eliminated, while for the same period on the subsequent days from 45 to 55 grams were exhaled. The minimum carbon dioxide elimination was reached on the last day.

The largest consumption of oxygen occurred on the first day and the smallest on the last day. The marked increase in the absorption of oxygen that would naturally be expected as a result of extra muscular work is not apparent during the second period of the first day. The difficulty of determining the respiratory quotient and especially the oxygen consumption for short periods during severe muscular work has previously been pointed out.[a]

In general, the falling off in the consumption of oxygen from day to day is roughly proportional to the decreasing quantities of carbon dioxide eliminated.

ELEMENTS KATABOLIZED IN THE BODY.

The amounts of elements katabolized, as computed from the result of the various elementary analyses, are given in table 70.

Elements and materials katabolized in the body.—The elements katabolized from the body and the amounts of katabolized materials (computed by means of the formulæ) are given for each day in table 71. Of especial significance

[a] U. S. Dept. Agriculture, Office of Exp. Sta. Bul. 175.

is the marked fluctuation of the protein katabolized, the quantity for the first day being very small, i. e., 35.04 grams. The usual large katabolism of carbohydrates takes place on the first day, while on the 3 succeeding days the loss is much less and very constant.

TABLE 70.—*Elements katabolized in body—Metabolism experiment No. 71.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Jan. 7, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	589.12	....	....	....	589.12	....
Water in urine	1133.99	....	....	126.89	1007.10	....
Solids in urine	25.51	5.84	5.22	1.16	5.64	7.65
Water of respiration [1]	744.84	....	....	83.35	661.49	....
Carbon dioxide	669.04	....	182.45	....	486.59	....
Total	2573.38	5.84	187.67	211.40	2160.82	7.65
Loss	1984.26	5.84	187.67	211.40	1571.70	7.65
Second day, Jan. 8, 1905.						
Income: Oxygen from air	554.11	....	....	....	554.11	....
Outgo:						
Water in urine	1984.11	....	....	222.02	1762.09	....
Solids in urine	36.99	11.04	8.29	2.02	9.58	6.06
Water of respiration [1]	665.19	....	....	74.43	590.76	....
Carbon dioxide	570.17	....	155.51	....	414.66	....
Total	3256.46	11.04	163.80	298.47	2777.09	6.06
Loss	2702.35	11.04	163.80	298.47	2222.98	6.06
Third day, Jan. 9, 1905.						
Income: Oxygen from air	537.97	....	....	....	537.97	....
Outgo:						
Water in urine	2500.68	....	....	279.83	2220.85	....
Solids in urine	40.92	13.10	8.64	2.29	11.04	5.85
Water of respiration [1]	567.66	....	....	63.52	504.14	....
Carbon dioxide	553.97	....	151.09	....	402.88	....
Total	3663.23	13.10	159.73	345.64	3138.91	5.85
Loss	3125.26	13.10	159.73	345.64	2600.94	5.85
Fourth day, Jan. 10, 1905.						
Income: Oxygen from air	492.74	....	....	....	492.74	....
Outgo:						
Water in urine	1449.25	....	....	162.17	1287.08	....
Solids in urine	36.55	10.74	7.73	2.08	10.06	5.94
Water of respiration [1]	517.66	....	....	57.93	459.73	....
Carbon dioxide	508.13	....	138.58	....	369.55	....
Total	2511.59	10.74	146.31	222.18	2126.42	5.94
Loss	2018.85	10.74	146.31	222.18	1633.68	5.94

[1] Includes also water of perspiration.

Balance of water.—The usual method of obtaining the actual loss of water to the body was followed in this experiment. While the quantity of urine voided results in a large elimination of preformed water, this output is nearly compensated by the unusually large amounts of water consumed. The amounts lost

(column *f*, table 72) were fairly constant save on the last day of the experiment. The data are given in table 72.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

As in preceding experiments, actual weighings were used to check the computed losses of body material. From the records of the weights of drinking-

TABLE 71.—*Elements and materials katabolized in body—Metabolism experiment No. 71.*

Date.	(*a*) Nitrogen.	(*b*) Carbon.	(*c*) Hydrogen.	(*d*) Oxygen.	(*e*) Water.	(*f*) Protein.	(*g*) Fat.	(*h*) Carbohydrates (as glycogen).	(*i*) Ash.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 7–8.....	5.84	187.67	211.40	1571.70	1643.94	35.04	116.53	181.64	7.65
Jan. 8–9.....	11.04	163.80	298.47	2222.98	2449.08	66.24	152.29	29.69	6.06
Jan. 9–10....	13.10	159.73	345.64	2600.94	2877.07	78.60	142.90	22.04	5.85
Jan. 10–11....	10.74	146.31	222.18	1633.68	1791.12	64.44	133.01	25.33	5.94
Total, 4 days.	40.72	657.51	1077.69	8029.30	8761.21	244.32	544.73	258.70	25.50

TABLE 72.—*Distribution of intake and outgo of water—Metabolism experiment No. 71.*

Date.	Outgo from the body.			Balance of preformed water.			(*g*) Water of oxidation of organic hydrogen (*c*—*d*).
	(*a*) Water of urine.	(*b*) Water of respiration and perspiration.	(*c*) Total (*a*+*b*).	(*d*) Preformed (katabolized) water in outgo.	(*e*) Intake in drink.	(*f*) Loss of preformed water (*d*—*e*).	
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 7–8	1134.0	744.8	1878.8	[1]1643.9	1204.4	[1]439.5	234.9
Jan. 8–9	1984.1	665.2	2649.3	[1]2449.1	1973.2	[1]475.9	200.2
Jan. 9–10	2500.7	567.7	3068.4	[1]2877.1	2312.9	[1]564.2	191.3
Jan. 10–11	1449.2	517.7	1966.9	1791.1	1485.3	305.8	175.8
Total for 4 days....	7068.0	2495.4	9563.4	8761.2	6975.8	1785.4	802.2
Average per day....	1767.0	623.8	2390.8	2190.3	1744.0	446.3	200.5

[1] Does not include water of feces. (See p. 122.)

water and oxygen consumed, the total income is computed and recorded in line *c* of table 73. The outgo requires special consideration. Contrary to the experience of the subjects of experiments Nos. 59, 68, and 69, the subject of this experiment defecated on each of the first 3 days. The large amount of vegetable material in his diet affected peculiarly the passage of feces,[a] as is espe-

[a] For discussion of this point, see Section on Feces, Part 3, of this report.

cially noticeable on the first day. The weights of fresh feces were as follows: At 9h 36m a. m., January 7, 241.5 grams; at 7h 24m a. m., January 8, 41.3 grams; and at 7h 24m a. m., January 9, 48 grams. As was customary in all the fasting experiments, the subject had taken a gelatin capsule filled with lampblack with the last meal immediately preceding the fast. Since none of this fecal matter was colored with charcoal, it was obvious that it belonged distinctly to food taken previously. It was therefore not a product resulting from fasting metabolism. Since, however, feces were actually passed they should be taken into consideration in the balance made in table 73.

TABLE 73.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 71.*

	Jan. 7-8.	Jan. 8-9.	Jan. 9-10.	Jan. 10-11.	Total for 4 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Water consumed...	1204.40	1973.20	2312.90	1485.30	6975.80	1743.95
(*b*) Oxygen............	589.12	554.11	537.97	492.74	2173.94	543.49
(*c*) Total (*a*+*b*)........	1793.52	2527.31	2850.87	1978.04	9149.74	2287.44
Outgo:						
(*d*) Urine[1]............	1459.50	1796.90	2138.30	2008.30	7403.00	1850.75
(*e*) Feces[2]............	241.50	41.30	48.00	....	330.80	82.70
(*f*) Carbon dioxide....	669.04	570.17	553.97	508.13	2301.31	575.33
(*g*) Water of respiration and perspiration............	744.84	665.19	567.66	517.66	2495.35	623.84
(*h*) Total (*d*+*f*+*g*).....	2873.38	3032.26	3259.93	3034.09	12199.66	3049.92
(*i*) Gain (+) or loss (−) of body material (*c*−*h*)..	−1079.86	−504.95	−409.06	−1056.05	−3049.92	−762.48
(*j*) Gain (+) or loss (−) of body-weight.........	−1091.00	−507.00	−418.00	−1114.00	−3130.00	−782.50

[1] The data in this line should not be confounded with urine data in other tables. (See explanation, p. 66.)
[2] Not included in the total outgo. (See p. 119.)

Comparison of lines *i* and *j* of table 73 shows very satisfactory agreement on the second and third days between the losses of body material and losses in weight. On the last day, however, there is a considerable error. The difficulties of securing the complete accuracy of this balance have already been dwelt upon.

In the previous fasting experiments here reported no feces had been passed during the experimental period. In this experiment, however, feces were passed on the first 3 days which evidently were the resultant of food taken previous to the fast. But as it was found impracticable to separate fasting feces from those of food preceding fasting, which were in this and some subsequent experiments excreted during the fasting period, the best method of using the weights in the computations was not clear. The uncertainty as to the nature of the feces seemed to make it desirable to eliminate them from the

TABLE 74.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 71.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Jan. 7	1 a.m. to 3 a.m.	77.6	37.9	[2] +13.2	[2] 128.7
	3 a.m. 5 a.m.	87.6	35.4	[2] −10.2	[2] 112.8
	5 a.m. 7 a.m.	92.8	36.8	[2] + 3.0	[2] 132.6
	Total	258.0	110.1	[2] + 6.0	[2] 374.1
Jan. 7–8	7 a.m. to 9 a.m.	173.2	49.5	−15.1	207.6
	9 a.m. 11 a.m.	235.2	49.3	− 7.6	[3] 276.9
	11 a.m. 1 p.m.	150.2	42.6	+11.7	204.5
	1 p.m. 3 p.m.	135.6	39.3	− 2.8	172.1
	3 p.m. 5 p.m.	119.8	42.6	−21.4	141.0
	5 p.m. 7 p.m.	134.4	40.7	+21.3	196.4
	7 p.m. 9 p.m.	138.3	43.0	−11.7	169.6
	9 p.m. 11 p.m.	98.9	31.4	−43.0	87.3
	11 p.m. 1 a.m.	76.3	34.0	+47.6	157.9
	1 a.m. 3 a.m.	73.8	31.2	+ 5.1	110.1
	3 a.m. 5 a.m.	80.4	21.0	+30.6	132.0
	5 a.m. 7 a.m.	93.8	30.8	− 9.8	114.8
	Total	1509.9	455.4	+ 4.9	1970.2
Jan. 8–9	7 a.m. to 9 a.m.	201.3	51.5	−12.4	240.4
	9 a.m. 11 a.m.	126.8	42.9	+12.6	182.3
	11 a.m. 1 p.m.	119.7	34.9	+13.6	168.2
	1 p.m. 3 p.m.	132.6	37.1	− 1.7	168.0
	3 p.m. 5 p.m.	90.5	32.6	− 7.6	115.5
	5 p.m. 7 p.m.	132.9	35.6	+ 4.5	173.0
	7 p.m. 9 p.m.	115.7	33.8	−11.2	138.3
	9 p.m. 11 p.m.	101.9	31.7	−36.1	97.5
	11 p.m. 1 a.m.	98.3	31.7	+41.0	171.0
	1 a.m. 3 a.m.	88.3	31.6	− 1.5	118.4
	3 a.m. 5 a.m.	81.6	29.0	+20.1	130.7
	5 a.m. 7 a.m.	82.1	33.1	+25.4	140.6
	Total	1371.7	425.5	+46.7	1843.9
Jan. 9–10	7 a.m. to 9 a.m.	180.0	32.3	−27.6	184.7
	9 a.m. 11 a.m.	111.6	31.8	+10.7	154.1
	11 a.m. 1 p.m.	129.3	28.3	+ 2.8	160.4
	1 p.m. 3 p.m.	123.4	30.4	− 5.1	148.7
	3 p.m. 5 p.m.	125.8	30.1	− 3.5	152.4
	5 p.m. 7 p.m.	131.4	32.4	+20.7	184.5
	7 p.m. 9 p.m.	130.7	29.4	−22.0	138.1
	9 p.m. 11 p.m.	125.6	30.1	−26.1	129.6
	11 p.m. 1 a.m.	52.1	27.7	+51.8	131.6
	1 a.m. 3 a.m.	95.9	28.0	−11.1	112.8
	3 a.m. 5 a.m.	82.6	27.3	+18.3	128.2
	5 a.m. 7 a.m.	76.6	27.0	+17.6	121.2
	Total	1365.0	354.8	+26.5	1746.3

[1] See pp. 42-49.
[2] Not corrected for change in body temperature and weight.
[3] Not corrected for 2.74 calories introduced electrically in magnetizing the fields of the bicycle ergometer.

TABLE 74.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Jan. 10–11	7 a.m. to 9 a.m.	161.0	32.3	−23.0	170.3
	9 a.m. 11 a.m.	119.3	27.0	+ 8.4	154.7
	11 a.m. 1 p.m.	118.4	27.0	+ 3.2	148.6
	1 p.m. 3 p.m.	119.1	27.7	− 4.7	142.1
	3 p.m. 5 p.m.	112.6	27.5	− 0.0	140.1
	5 p.m. 7 p.m.	112.0	30.5	+ 4.0	146.5
	7 p.m. 9 p.m.	125.8	27.2	−19.5	133.5
	9 p.m. 11 p.m.	96.5	25.3	−35.1	86.7
	11 p.m. 1 a.m.	62.5	26.4	+43.7	132.6
	1 a.m. 3 a.m.	88.2	27.5	− 0.9	114.8
	3 a.m. 5 a.m.	79.7	25.9	+11.9	117.5
	5 a.m. 7 a.m.	76.4	24.0	+17.8	118.2
	Total	1271.5	328.3	+ 5.8	1605.6

[1] See pp. 42-49.

energy and heat computations. As shown above, the feces passed during the experiment were not an excretory product as a result of fasting metabolism and had they been retained in the colon until the end of the experiment would have affected in no wise the heat or energy balance.[a] Indeed, in some of the fasting experiments the feces were artificially removed by means of an enema before the subject entered the chamber, and none were passed during the time of the experiment. Accordingly in the fasting experiments it was assumed that the feces were retained in the body, and hence the weight of material as well as the heat lost by cooling from body temperature to calorimeter temperature were computed and corrected for, in column *c* of table 74. Allowance has been made in line *j* of table 73 for feces passed, the amounts being deducted from the total loss of weight in order to make the data comparable with the balance of income and outgo. The feces passed during the fasting experiments were not analyzed.

OUTPUT OF HEAT.

The calorimetric measurements are summarized as usual and correction made for changes in body temperature and body-weight. The total heat production is recorded in column *d* of table 74. Although the data for the preliminary night are also included, it is to be borne in mind that the value of the results for these three periods is somewhat uncertain because of the necessary incompleteness of preliminary heat corrections.

[a] The reabsorption of small amounts of material in the large colon is probable, but hardly a quantitative factor.

Table 74 shows that the total heat production was greatest on the first day and smallest on the last day. The extra heat eliminated as a result of the muscular work during the second period of the first day was markedly evident, for on the first day there were 276.83 calories produced as against an average of less than 165 calories for the corresponding period of the remaining days.

BALANCE OF ENERGY.

Table 75 shows the method of deriving the computed heat production and the comparison of these results with the heat production as measured.

It is true of this experiment, as of No. 69, that the total energy derived from different sources was on each day larger than the heat production as measured. The smallest discrepancy occurred on the second and the largest

TABLE 75.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 71.*

Date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater (+) or less (—) than output.	
	From body protein.								
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).		(h) Amount (f—g).	(i) Proportion (h÷g).
1906.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Per ct.
Jan. 7–8	198	58	140	1112	761	2013	1970	+ 43	+2.2
Jan. 8–9	374	91	283	1453	124	1860	1844	+ 16	+0.9
Jan. 9–10....	444	99	345	1363	92	1800	1746	+ 54	+3.1
Jan. 10–11....	364	86	278	1269	106	1653	1606	+ 47	+2.9
Total, 4 days.	1380	334	1046	5197	1083	7326	7166	+160	....
Av. per day..	345	83	262	1299	271	1832	1792	+ 40	+2.2

on the third day. These discrepancies were respectively +0.9 and +3.1 per cent of the measured heat production. The average discrepancy for the 4 days was +40 calories or +2.2 per cent. While the percentage error is considerably greater than might be expected from the previous experiments made with this apparatus and from the results of a large number of alcohol check tests made with it, nevertheless in considering these percentage errors it is important to note that the actual quantity of heat measured is much smaller than in any experiment heretofore recorded. On the fourth day of this experiment the heat production was little over 1600 calories.

RELATIONS OF OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The oxygen and carbon dioxide thermal quotients and the respiratory quotients for the different periods of the 4 days of the experiment are given in table 76.

TABLE 76.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 71.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated. (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f ÷ g).
1905.								
Jan. 7:								
Preliminary:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1 a.m. to 3 a.m.	[1]128.7	35.4	27.5	42.7	33.2	21.8	24.8	0.88
3 a.m. 5 a.m.	[1]112.8	28.9	25.7	44.7	39.6	22.7	20.2	1.12
5 a.m. 7 a.m.	[1]132.6	48.7	36.7	51.8	39.0	26.4	34.1	.77
Total.......	[1]374.1	113.0	30.2	139.2	37.2	70.9	79.1	.90
Jan. 7–8:								
7 a.m. to 9 a.m.	207.6	77.3	37.2	86.1	41.5	43.8	54.1	.81
9 a.m. 1 a.m.	276.8	71.5	25.8	105.2	38.0	53.6	50.0	1.07
11 a.m. 11 p.m.	204.5	51.6	25.3	61.6	30.1	31.4	36.1	.87
1 p.m. 3 p.m.	172.1	50.6	29.4	53.4	31.0	27.2	35.4	.77
3 p.m. 5 p.m.	141.0	45.6	32.3	51.3	36.4	26.1	31.9	.82
5 p.m. 7 p.m.	196.4	47.9	24.4	51.7	26.3	26.3	33.5	.79
7 p.m. 9 p.m.	169.6	56.0	33.0	60.6	35.7	30.9	39.2	.79
9 p.m. 1 p.m.	87.3	36.5	41.8	39.1	44.8	19.9	25.6	.78
11 p.m. 11 a.m.	157.9	35.0	22.2	39.9	25.3	20.3	24.5	.83
1 a.m. 3 a.m.	110.1	37.1	33.7	41.1	37.3	20.9	26.0	.81
3 a.m. 5 a.m.	132.0	40.2	30.5	38.5	29.1	19.6	28.2	.70
5 a.m. 7 a.m.	114.9	39.8	34.7	40.5	35.3	20.6	27.9	.74
Total.......	1970.2	589.1	29.9	669.0	34.0	340.6	412.4	.83
Jan. 8–9:								
7 a.m. to 9 a.m.	240.4	74.1	30.8	74.7	31.1	38.0	51.8	.73
9 a.m. 11 a.m.	182.3	67.7	37.1	54.7	30.0	27.8	47.4	.59
11 a.m. 1 p.m.	168.2	46.5	27.7	53.3	31.7	27.2	32.6	.83
1 p.m. 3 p.m.	168.0	54.7	32.6	52.7	31.4	26.8	38.3	.70
3 p.m. 5 p.m.	115.5	31.9	27.6	39.1	33.9	19.9	22.3	.89
5 p.m. 7 p.m.	173.0	48.4	28.0	48.5	28.0	24.7	33.9	.73
7 p.m. 9 p.m.	138.3	52.6	38.0	50.3	36.4	25.6	36.8	.70
9 p.m. 11 p.m.	97.5	33.0	33.8	36.8	37.8	18.8	23.1	.81
11 p.m. 1 a.m.	170.9	38.3	22.4	41.2	24.1	21.0	26.8	.78
1 a.m. 3 a.m.	118.4	39.7	33.5	39.4	33.3	20.0	27.8	.72
3 a.m. 5 a.m.	130.7	33.6	25.7	40.1	30.7	20.4	23.5	.87
5 a.m. 7 a.m.	140.6	33.6	23.9	39.4	28.0	20.1	23.6	.85
Total.......	1843.8	554.1	30.1	570.2	30.9	290.3	387.9	.75
Jan. 9–10:								
7 a.m. to 9 a.m.	184.7	66.5	36.0	62.7	33.9	31.9	46.5	.69
9 a.m. 11 a.m.	154.1	44.5	28.9	44.5	28.8	22.6	31.1	.73
11 a.m. 1 p.m.	160.4	42.6	26.6	47.2	29.4	24.0	29.8	.81
1 p.m. 3 p.m.	148.7	49.7	33.4	53.2	35.8	27.1	34.8	.78
3 p.m. 5 p.m.	152.4	50.6	33.2	51.4	33.8	26.2	35.4	.74
5 p.m. 7 p.m.	184.5	48.5	26.3	51.1	27.7	26.0	34.0	.77
7 p.m. 9 p.m.	138.1	47.5	34.4	46.2	33.4	23.5	33.3	.71
9 p.m. 11 p.m.	129.6	56.2	43.4	57.4	44.3	29.2	39.3	.74
11 p.m. 1 a.m.	131.6	32.3	24.6	36.3	27.6	18.5	22.6	.82
1 a.m. 3 a.m.	112.8	32.1	28.5	33.5	29.7	17.1	22.5	.76
3 a.m. 5 a.m.	128.2	36.7	28.6	37.2	29.0	18.9	25.7	.74
5 a.m. 7 a.m.	121.2	30.8	25.4	33.3	27.5	17.0	21.6	.79
Total.......	1746.3	538.0	30.8	554.0	31.7	282.0	376.6	.75

[1] See p. 121.

TABLE 76.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Date and period.		(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b+a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d+a).	(f) Volume of carbon dioxide eliminated (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f+g).
1905. Jan. 10–11:		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m.	9 a.m.	170.3	55.1	32.4	56.8	33.3	28.9	38.6	0.75
9 a.m.	11 a.m.	154.7	41.8	27.0	45.4	29.4	23.1	29.2	.79
11 a.m.	1 p.m.	148.6	41.4	27.9	46.5	31.3	23.7	29.0	.82
1 p.m.	3 p.m.	142.1	53.5	37.6	48.1	33.8	24.5	37.5	.65
3 p.m.	5 p.m.	140.1	46.5	33.2	47.1	33.6	24.0	32.5	.74
5 p.m.	7 p.m.	146.5	42.9	29.3	44.3	30.2	22.6	30.0	.75
7 p.m.	9 p.m.	133.4	45.1	33.8	46.6	34.9	23.7	31.6	.75
9 p.m.	11 p.m.	86.8	36.0	41.5	37.2	42.9	18.9	25.2	.75
11 p.m.	1 a.m.	132.6	32.2	24.3	35.4	26.7	18.0	22.5	.80
1 a.m.	3 a.m.	114.9	36.9	32.2	33.2	29.0	16.9	25.9	.65
3 a.m.	5 a.m.	117.5	34.1	29.0	31.8	27.1	16.2	23.9	.68
5 a.m.	7 a.m.	118.2	27.2	23.0	35.7	30.2	18.2	19.0	.96
Total.......		1605.7	492.7	30.7	508.1	31.7	258.7	344.9	.75

The oxygen thermal quotients undergo marked changes from one period to another. For example, between 9 and 11 p. m. it is in general very much larger than between 11 p. m. and 1 a. m. owing to the difficulty of accurate oxygen determination in periods in which there are differences in the degree of muscular activity and apparent changes in temperature at the beginning and end of the period due to difference in body position with reference to the thermometers. Similar irregularities are noted in the other quotients.

It is worthy of note that for the second period of the first day an unusually high respiratory quotient is recorded. This value has no significance owing to the errors already pointed out in the determination of oxygen consumption for this period. The daily respiratory quotient after the first day remained practically constant.

METABOLISM EXPERIMENT NO. 72.

This experiment, which continued only one day, immediately followed the 4-day fasting experiment No. 71. It had been planned to continue the experiment for several days, but the subject was unwilling to remain in the chamber more than one day. The experimental data are therefore necessarily somewhat incomplete and unsatisfactory, but so far as the measurements of katabolism are concerned they are sufficiently accurate to warrant their presentation. The statistical data for the experiment appear in the tables which follow.

Notes from diary.—The experiment began at 7 a. m., January 11, 1905, and continued 24 hours. As in the previous experiment, the subject, S. A. B., took copious notes concerning his physical condition. Extracts from these notes are given below.

Notes from diary.

Jan. 11, 1905:

7h30m a. m. Feel considerably better. Am not drinking much water, because it tastes very badly.

9h15m a. m. Defecation.

1h30m p. m. Drank 1½ bottles of milk. Feel very much stronger and my brain is clearing up quickly; can think more. The redness of my eyes has passed away and they are considerably clearer.

4h30m p. m. Have just finished another portion of milk, which tasted very good. Am very hungry.

5h30m p. m. Have had no hiccoughs or any pain of the heart or cramps in stomach. Am becoming stronger, and my nerves are more under control than they have been, even before I entered calorimeter. Tongue became coated after drinking milk, but it will clear up after I have eaten some fruit and had a good meal.

8 p. m. Have just finished another portion of milk; enjoyed it very much. Am longing for outdoor exercise and fresh air.

Jan. 12, 1905:

Did not sleep any last night; was not uncomfortable in any way, simply could not sleep. Came out of calorimeter at 7h15m a. m.

OUTSIDE CALORIMETER.

7h30m a. m. Feel very dizzy and can hardly walk.

10 a. m. Walked a quarter of a mile to my room.

1h30m p. m. Walked from my room to the laboratory (quarter mile) and felt very tired and weak; then I walked a total distance of three-quarters of a mile and was glad to take a rest.

Pulse.—The subject took his pulse 6 times during the day of this experiment, and 3 times the day after he had left the calorimeter. The records are given below.

Pulse rate—Experiment No. 72.[1]

Time.	Pulse rate.	Time.	Pulse rate.
Jan. 11, 7h 15m a. m.	[2]60	Jan. 11, 8h 30m p. m.	70
7 30 a. m.	[3]68	Jan. 12,[5] 7 30 a. m.	70
10 30 a. m.	[4]64	10 32 a. m.	72
1 30 p. m.	70	1 30 p. m.	72
5 30 p. m.	71		

[1] Pulse taken while sitting unless otherwise specified.
[2] Standing.
[3] After eating orange juice.
[4] After eating milk.
[5] Outside calorimeter.

Routine.—The routine differed little from that of the preceding days, save that it included the taking of food. A fair idea of the course of the day's events can be obtained from the record of body movements given below.

Movements of subject.—Duration, 1 day, from Jan. 11, 7 a. m., to Jan. 12, 7 a. m., 1905.

January 11.

A. M.	
7h 00m	rise, urinate.
7 06 } 7 10 }	weigh self, etc.
7 12	food aperture.
7 15	stand, count pulse.
7 16	suck orange.
7 18	sit.
7 20	move about.
7 24	food aperture.
7 26	telephone.
7 28	sit, suck orange.
7 30	rise, move about.
7 32	stand.
7 36	count pulse, put on coat.
7 40	sit.
7 42	study.
8 30	telephone.
8 34	rise, food aperture.
8 36	sit.
8 38	study.
9 12	telephone.
9 14	study.
9 38	stop studying.
9 40	close curtain.
9 45	defecate.
9 52	open curtain.
9 54	lean on table, read.
9 56	telephone, sit.
10 28	telephone, rise, food aperture.
10 30	sit, count pulse, write.
A. M.	
10h 34m	rise, food aperture.
10 36	lean on table, read.
10 38	sit, study.
11 04	rise, move about, food aperture.
11 06	sit, study.
11 16	lean on table, write.
11 18	telephone.
11 20	food aperture, walk about.
11 22	food aperture.
11 24	drink, write.
11 26	sit, read.
P. M.	
12h 04m	drink.
12 12	sit, comb hair.
12 18	read.
12 34	telephone.
12 38	drink.
12 44	rinse bottle.
1 02	rise, move about, urinate.
1 04	lean on table, read.
1 22	sit.
1 27	food aperture.
1 30	count pulse, write.
1 52	stand.
2 00	food aperture.
2 04	lean on table, write.
2 26	move about.
2 51	food aperture.
3 04	telephone.
P. M.	
3h 10m	rise, move about.
3 17	food aperture.
3 18	sit, read.
4 06	rise, move about.
4 10	sit.
4 30	drink, write.
5 02	rise, move about, lean on table, write.
5 08	stand.
5 14	sit.
5 20	stand.
5 26	sit.
5 30	count pulse, write.
5 52	rise, telephone.
5 54	food aperture.
5 58	sit.
6 08	read.
6 20	stand.
6 22	telephone.
6 36	lean on table, read.
6 44	sit, read.
7 00	urinate.
7 26	stand, read.
7 58	drink.
7 59	food aperture.
8 00	write.
8 30	count pulse, sit, food aperture.
9 38	drink.
9 40	open bed.
9 42	lie.
11 00	undress.
11 02	close curtain, urinate, retire.

CONSUMPTION OF WATER AND OXYGEN, AND ELIMINATION OF URINE, WATER-VAPOR, AND CARBON DIOXIDE.

Tables 77 to 81 have been explained in more or less detail in the preceding experiments. Since the methods followed in obtaining the data in these tables differ in no important respect from those used in corresponding tables of preceding experiments, no further discussion is here given.

TABLE 77.—*Record of water consumed*[1]*—Metabolism experiment No. 72.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	Total for day.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 11-12, 1905.........	298.6	196.9	128.8	55.6	55.6	735.5

[1] Period during which water was consumed was assumed in some instances. (See p. 25.)

TABLE 78.—*Determinations in urine per period and per day—Metabolism experiment No. 72.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a+b).	(d) Reaction.	(e) Nitrogen.
1905.		*Grams.*		c. c.		*Grams.*
Jan. 11-12.	7 a.m. to 1 p.m..	496.6	1.0067	493	Acid.........	3.71
	1 p.m 7 p.m..	463.9	1.0049	462	....do........	2.68
	7 p.m. 11 p.m..	221.6	1.0067	220	....do........	1.67
	11 p.m. 7 a.m..	314.3	1.0080	312	....do........	2.60
	Total..........	1496.4	....	1487	....	10.66
	Total by composite........	1496.4	1.0065	1487	Acid.........	10.71

TABLE 79.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 72 (Jan. 11-12, 1905).*

(a) Weight..............grams..1496.40	(i) Oxygen (by difference) in organic matter, $e-(f+g+h)$..grams..9.54
(b) Water.................do....1463.33	(j) Phosphorus..............do.... .714
(c) Solids $(a-b)$...........do.... 33.07	(k) Phosphoric acid by fusion (P_2O_5), grams......................1.635
(d) Ash...................do.... 3.59	(l) Sulphur................grams.. .578
(e) Organic matter $(c-d)$...do.... 29.48	(m) Sulphur trioxide (SO_3)....do....1.442
(f) Nitrogen..............do.... 10.66	(n) Heat of combustion....calories.. 84
(g) Carbon................do.... 7.33	
(h) Hydrogen in organic matter, grams.................... 1.95	

TABLE 80.—*Record of water of respiration and perspiration—Metabolism experiment No. 72.*

Date.	Period.	Total am'nt of vapor in chamber at end of period.	Total water of respiration and perspiration.[1]	Date.	Period.	Total am'nt of vapor in chamber at end of period.	Total water of respiration and perspiration.[1]
1905.	Preliminary:	*Grams.*	*Grams.*	1905.		*Grams.*	*Grams.*
Jan. 11	5 a.m. to 7 a.m.	23.7	...	Jan. 11-12.	7 p.m. to 9 p.m.	31.3	46.2
					9 p.m. 11 p.m.	25.7	40.2
Jan. 11-12.	7 a.m. to 9 a.m.	29.5	53.0		11 p.m. 1 a.m.	28.0	42.3
	9 a.m. 11 a.m.	29.7	51.9		1 a.m. 3 a.m.	26.4	43.5
	11 a.m. 1 p.m.	28.1	44.0		3 a.m. 5 a.m.	26.3	39.5
	1 p.m. 3 p.m.	28.6	52.8		5 a.m. 7 a.m.	25.5	43.2
	3 p.m. 5 p.m.	31.1	46.3		Total.......	....	544.9
	5 p.m. 7 p.m.	29.3	42.0				

[1] Allowance has been made for 22.62 grams water lost from absorbers and miscellaneous articles.

ELEMENTS AND MATERIALS KATABOLIZED IN BODY.

It has already been emphasized in the discussion of experiment No. 70, the first experiment with food, that in the tables showing the disintegration of body material, the katabolism and the effect of the absorption of food are considered independently. In this experiment likewise, in computing the materials actually katabolized from the body, drinking-water and food are not taken into consideration. From the loss of elements as given in table 82 and by use of the formulæ previously quoted, it is calculated that there was a loss of 1824.62 grams of water, 63.96 grams of protein, 147.47 grams of fat,

TABLE 81.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 72.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
		Grams.	*Grams.*	*Liters.*	*Grams.*
1905. Jan. 11......	Preliminary: 5 a. m. to 7 a. m..	19.0	....	1090.2	....
Jan. 11–12...	7 a. m. to 9 a. m..	30.4	56.8	1084.1	62.9
	9 a. m. 11 a. m..	28.1	48.8	1076.7	46.4
	11 a. m. 1 p. m..	28.9	48.7	1073.7	47.7
	1 p. m. 3 p. m..	31.1	59.4	1071.0	47.1
	3 p. m. 5 p. m..	29.5	39.2	1063.7	56.2
	5 p. m. 7 p. m..	28.7	44.8	1061.3	41.8
	7 p. m. 9 p. m..	31.7	47.1	1052.1	47.1
	9 p. m. 11 p. m..	24.2	39.7	1058.3	34.4
	11 p. m. 1 a. m..	26.2	39.0	1037.9	39.1
	1 a. m. 3 a. m..	21.8	34.1	1035.2	32.0
	3 a. m. 5 a. m..	20.7	30.5	1022.1	30.4
	5 a. m. 7 a. m..	20.2	36.5	1004.8	31.8
	Total...........	....	524.6	....	516.9

TABLE 82.—*Elements katabolized in body—Metabolism experiment No. 72.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Jan. 11, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	516.85	....	....	....	516.85	....
Outgo:						
Water in urine.............	1463.33	....	....	163.75	1299.58	....
Solids in urine..............	33.07	10.66	7.33	1.95	9.54	3.59
Water of respiration [1].......	544.84	....	....	60.97	483.87	....
Carbon dioxide.............	524.58	....	143.06	....	381.52	....
Total....................	2565.82	10.66	150.39	226.67	2174.51	3.59
Loss......................	2048.97	10.66	150.39	226.67	1657.66	3.59

[1] Includes also water of perspiration.

and 10.31 grams of carbohydrates (considered as glycogen). The loss of ash in the urine amounted to 3.59 grams.

OUTPUT OF HEAT.

The essential data involved in the calculation of the heat production are recorded in table 83.

TABLE 83.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 72.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Jan. 11–12...	7 a. m. to 9 a. m..	138.9	32.5	+14.4	185.8
	9 a. m. 11 a. m..	126.2	31.8	+ 0.3	158.3
	11 a. m. 1 p. m..	123.7	27.2	+10.0	160.9
	1 p. m. 3 p. m..	126.6	32.4	+15.4	174.4
	3 p. m. 5 p. m..	128.2	28.5	− 3.3	153.4
	5 p. m. 7 p. m..	131.0	26.0	− 6.5	150.5
	7 p. m. 9 p. m..	117.7	28.4	− 4.3	141.8
	9 p. m. 11 p. m..	110.8	24.9	−13.4	122.3
	11 p. m. 1 a. m..	51.4	26.2	+12.1	89.7
	1 a. m. 3 a. m..	96.2	26.9	+ 6.2	129.3
	3 a. m. 5 a. m..	81.2	24.5	−11.6	94.1
	5 a. m. 7 a. m..	80.3	26.7	+ 9.0	116.0
	Total...........	1312.2	336.0	+28.3	1676.5

[1] See p. 42.

BALANCE OF ENERGY.

In this experiment, as in No. 70, the computed energy of the oxidized body material is compared with the heat production.

TABLE 84.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 72 (Jan. 11-12, 1905).*

Energy derived from different sources:	Energy derived from different sources—Continued.
From body protein—	(f) Total ($c+d+e$)........calories..1727
(a) Energy of protein katabolized, calories.................... 861	(g) Total heat production... do....1676
(b) Potential energy of urine, calories.................... 84	Energy from body material greater (+) or less (−) than output:
(c) Net energy ($a-b$)...calories.. 777	(h) Amount ($f-g$)....... calories..+51
(d) From body fat..........do....1407	(i) Proportion ($h÷g$).... per cent..+ 3
(e) From body glycogen.....do.... 48	

RELATIONS OF OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The oxygen and carbon dioxide thermal quotients and the respiratory quotients for this experiment are given in table 85.

EFFECT OF INGESTION OF FOOD.

Diet.—Following the fasts which the subject had previously made in private, he was accustomed to break the fast by taking small quantities of orange juice, and hence this material was included in the diet on this day. Later in the day milk with an admixture of cream was taken.

TABLE 85.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 72.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d × 0.5091).	(g) Volume of oxygen consumed (b × 0.7).	(h) Respiratory quotient (f ÷ g).
1905. Jan. 11–12:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m. to 9 a.m.	185.8	63.9	33.9	56.8	30.6	28.9	44.0	0.66
9 a.m. 11 a.m.	158.4	46.4	29.3	48.8	30.8	24.9	32.4	.77
11 a.m. 1 p.m.	160.9	47.7	29.6	48.7	30.3	24.8	33.4	.74
1 p.m. 3 p.m.	174.4	47.1	27.0	59.4	34.1	30.2	32.9	.92
3 p.m. 5 p.m.	153.4	56.2	36.6	39.2	25.6	20.0	39.4	.51
5 p.m. 7 p.m.	150.4	41.8	27.8	44.8	29.8	22.8	29.3	.78
7 p.m. 9 p.m.	141.8	47.1	33.2	47.1	33.2	24.0	33.0	.73
9 p.m. 11 p.m.	122.3	34.4	28.2	39.7	32.5	20.2	24.1	.84
11 p.m. 1 a.m.	89.7	39.1	43.6	39.0	43.5	19.9	27.4	.73
1 a.m. 3 a.m.	129.3	32.0	24.8	34.1	26.4	17.3	22.4	.77
3 a.m. 5 a.m.	94.1	30.4	32.3	30.5	32.4	15.5	21.3	.73
5 a.m. 7 a.m.	116.0	31.8	27.4	36.5	31.5	18.6	22.3	.84
Total........	1676.5	516.9	30.8	524.6	31.3	267.1	361.8	.74

TABLE 86.—*Percentage composition of food—Metabolism experiment No. 72.*

	Milk.[1]	Orange juice.[2]		Milk.[1]	Orange juice.[2]
Water..........per cent..	80.55	87.63	Nitrogen.......per cent..	0.49	0.09
Protein............do....	3.06	.54	Carbon............do....	11.70	4.52
Fat....... ....do....	10.74	....	Hydrogen..........do....	1.81	.77
Carbohydrates......do....	4.99	11.44	Heat of combustion per gram.........calories..	1.359	.459
Ash...............do....	.66	.39			

[1] Laboratory number, 3818.
[2] Not analyzed. The percentage composition is an average of two samples used in experiments Nos. 74 and 76.

Analysis of food.—The statement was made on page 126 that the data of this experiment were somewhat incomplete. This lack of completeness is first noticeable in table 86, where no percentage composition of feces appears. The reason for the omission of data on feces is explained beyond. The table does show, however, the percentage composition in terms of nutrients and elements of the ingested food, while table 87 shows the kinds and amounts of food, and the nutrients and elements contained in it.

Materials absorbed from food.—Feces amounting to 70.30 grams were passed at 9.45 a. m., January 11, but it was obviously impossible that they resulted from the food consumed during the same day. Defecations occurred on the 3 days following the experiment, and the separation as made gave 219.3 grams as the amount of feces for this day. Previous experience had already

TABLE 87.—*Weight, composition, and heat of combustion of food—Metabolism experiment No. 72.*

Laboratory number.	Kind of food.	(a) Weight.	(b) Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
3818	Milk	1253.00	1009.29	38.34	134.57	62.53
....	Orange juice	106.30	93.15	0.58	....	12.16
	Total for day	1359.30	1102.44	38.92	134.57	74.69

Laboratory number.	Kind of food.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(j) Oxygen (by difference).	(k) Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3818	Milk	8.27	6.14	146.60	22.68	60.02	1703
....	Orange juice	0.41	0.10	4.80	0.82	7.02	49
	Total for day	8.68	6.24	151.40	23.50	67.04	1752

TABLE 88.—*Elements and materials absorbed from dry matter of food*[1]*—Metabolism experiment No. 72 (Jan. 11, 1905).*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Solids in food	256.86	6.24	151.40	23.50	67.04	8.68
Absorbed	....	5.55	142.32	22.09	65.03	5.12
Protein	[2] 33.30	....	....	....	....	....
Fat	[2] 121.69	....	....	....	....	....
Glycogen	[2] 72.30	....	....	....	....	....
Ash	5.12	....	....	....	....	....

[1] To obtain the amounts of the elements of dry matter absorbed, the average percentages of elements of water-free substance absorbed in experiments Nos. 70, 74, and 76 are used. These averages are as follows: Nitrogen, 89 per cent; carbon, 94 per cent; hydrogen, 94 per cent; oxygen, 97 per cent; ash, 59 per cent. (See p. 133.)
[2] In terms of body material.

shown that a satisfactory separation of feces from a food experiment lasting only 1 day was not to be expected, and since the amount found was abnormally large, it is believed that the separation as shown by the discoloration of the feces with lampblack was erroneous. It therefore became necessary to estimate the quantity of material absorbed from the food during this experiment. Since the diet consisted essentially of milk it was not difficult to obtain an average

absorption based upon results in other experiments. From data obtained in two 3-day experiments with food made later with this subject, and one experiment of 3 days' duration already presented, i. e., experiment No. 70, average results were found and from these data it was possible to compute the amounts of the elements in the dry matter absorbed. This estimate is recorded in table 88. By means of the formulæ previously given, the quantities of protein, fat, and glycogen in terms of body material absorbed from the food have been computed and are also recorded in this table.

TABLE 89.—*Amounts of protein, fat, and glycogen absorbed*[1] *from food and energy of each*[2]*—Metabolism experiment No. 72 (Jan. 11-12, 1905).*

Protein:		Glycogen:	
(a) Amount.........grams..	33.30	(e) Amount.........grams..	72.30
(b) Energy........calories..	188	(f) Energy........calories..	303
Fat:		(g) Total energy (b + d + f), calories..............	1652
(c) Amount.........grams..	121.69		
(d) Energy........calories..	1161		

[1] In terms of body material. (See p. 132.)
[2] Factors for heat of combustion per gram of protein, 5.65 calories; of fat, 9.54 calories; of glycogen, 4.19 calories.

Energy of material absorbed from food.—Having computed the amounts of nutrients absorbed in terms of body material, the energy was found as heretofore by use of the factors for heat of combustion. The results are given in table 89.

TABLE 90.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 72 (Jan. 11-12, 1905).*

Income:	*Grams.*	Outgo—Continued.	*Grams.*
(a) Food......................	1359.30	(g) Carbon dioxide.............	524.58
(b) Water consumed............	735.50	(h) Water of respiration and perspiration..................	544.84
(c) Oxygen....................	516.85	(i) Total (e+f+g+h)..........	2535.22
(d) Total (a+b+c).............	2611.65	(j) Gain of body material (d—i)..	+76.43
Outgo:		(k) Gain of body-weight........	+49.70
(e) Urine[1]...................	1895.50		
(f) Feces.....................	70.30		

[1] The data in this line should not be confounded with urine data in other tables. (See explanation, p. 66.)

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

In connection with the data given below, which record the amounts of intake and output of the body, the fact that the amount of feces is lacking in the preceding tables of this experiment does not vitiate the results shown in table 90, for in this table we are concerned only with the amounts of feces passed from 7 a. m., January 11, to 7 a. m., January 12, and not with the relation of such amounts to the metabolism of this day. As a matter of fact, the 70.30 grams of feces recorded in line *f* were from food eaten several days prior to

January 11. Nevertheless, in order to obtain the true loss of body-weight, they must be included in the total outgo.

BALANCE OF INTAKE AND OUTPUT.

It has previously been explained that the amounts of nutrients and energy of absorbed food are assumed, not determined as the differences between the nutrients and energy of food and feces. The difficulties of striking balances with data as meager as these are readily seen. Too great stress therefore should not be laid upon the value of the results thus obtained.

TABLE 91.—*Distribution of intake and outgo of water—Metabolism experiment No. 72.*

Date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c—d).
	(a) Water of urine and feces.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.[1]	(e) Intake in food and drink.	(f) Loss of preformed water (d—e).	
1905	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Jan. 11–12............	1514.3	544.8	2059.1	1875.6	1837.9	[2]37.7	183.5

[1] Includes 51 grams of water assumed as being eliminated in feces. (See p. 135.)
[2] Takes account of water assumed for feces.

TABLE 92.—*Balance of intake and output of nutrients, ash, and energy—Metabolism experiment No. 72 (Jan. 11-12, 1905).*

	(a) Computed from elements absorbed from food.[1]	(b) Katabolized.	(c) Gain (+) or loss (—) to body.	(d) Of absorbed food.[2]	(e) Heat production plus potential energy of urine.	(f) Gain (+) or loss (—) to body.
Body protein.....grams..	33.30	63.96	— 30.66	....	....	....
Body fat..........do....	121.69	147.47	— 25.78	....	....	....
Body carbohydrates.do....	72.30	10.31	+ 61.99	....	....	....
Ash..............do....	5.12	3.59	+ 1.53	....	....	....
Energy.........calories..	....	....	....	1652	1760	—108

[1] Calculated on the basis of dry matter of food. (See table 88.)
[2] Estimated. (See p. 133.)

Balance of water.—As in experiment No. 70, the water balance has been isolated from the others in order to simplify the tabular matter. This water balance is given above in table 91, which also shows the different sources of the water of outgo and the water resulting from the oxidation of organic hydrogen. Special attention is called to column *f*, which shows an unusually small loss of preformed water to the body.

Allowance has been made in column *a* of table 91 for 51 grams of water excreted in the feces. This amount was obtained by multiplying the amount of feces passed by the average per cent of water of feces in experiments Nos. 74 and 76, and hence is an assumption. The fact that the water content of the feces passed on this day was not known, however, made the assumption necessary. It therefore follows that the loss of preformed water shown in column *f* of the table may not be the true loss, though there are indications that the amount is but a few grams from the actual.

Nutrients, ash, and energy.—In table 92 are recorded the balances of nutrients, ash, and energy. As previously explained (see table 88) the data for absorbed materials are estimated on the basis of dry matter. The energy shown in column *d*, table 92, is computed by use of the heats of combustion of body material as applied to the amounts given in column *a* of the table.

METABOLISM EXPERIMENT NO. 73.

The subject of this experiment was also the subject of experiments Nos. 71 and 72. Following experiment No. 72, from January 12 to January 27 (inclusive), he remained outside the calorimeter and lived on a diet of his own selection.

This diet consisted for the most part of fruits, nuts, and cereals, very little meat being eaten. The return to his normal physical and mental condition was so rapid that by the end of two weeks he was ready to begin another fast. Accordingly, on the evening of January 27 he entered the respiration chamber with the intention of remaining for a 5-day fast. The preliminary period began at 1 a. m., January 28, the experiment proper beginning 6 hours later. As usual the analyses of the respiratory products were made every 2 hours.

Notes from diary, pulse records, and records of body movements.—As in previous experiments, the subject, S. A. B., kept a diary. This diary has been abstracted, and a number of irrelevant notes omitted. The portions which seemed essential are reported below, together with the pulse records made by the subject, and the record of the grosser body movements.

Notes from diary.

Jan. 27, 1905 (preliminary night):

9^h20^m p. m. Entered calorimeter.

Jan. 28, 1905:

7^h30^m a. m. Did not sleep well; awoke at 3 a. m. and fell asleep again at 5^h30^m a. m. My tongue is coated. Do not feel as nervous as in my former experiment.

9^h15^m a. m. Had a normal defecation.

12 m. Am in splendid condition for a fast; feel 100 per cent better than in my former experiment. Nerves are not overstrung.

2 p. m. Am drinking distilled water and like it very much.

4 p. m. Have a slight bilious headache and nausea; feel comfortable otherwise.

6 p. m. Headache is on left side of head only.

10 p. m. Feel sleepy. Have passed a very comfortable day; feel considerably better than in the previous experiment. Have raised some catarrhal phlegm during the day.

Jan. 29, 1905:

7^h30^m a. m. Passed a fairly good night. Slept continuously until 3^h30^m a. m.; from then on woke nearly every hour. My tongue has a whitish coating and there is a sour taste in my mouth; otherwise perfectly well.

10 a. m. My nose feels very dry; a speck of blood stained my handkerchief while blowing my nose.

12 m. Have been very quiet.

2 p. m. Feel very comfortable and surprisingly well. The distilled water tastes considerably better than the ordinary city water I drank in the previous experiment.

10 p. m. Have had a slight headache, but it did not last. Passed a very comfortable day. Some mucous from throat during the day.

Jan. 30, 1905:

7^h30^m a. m. Have slept considerably better than the night previous. Slept continuously from 11 p. m. to 4^h45^m a. m.; fell asleep again at 5^h15^m a. m., and awakened at 6^h45^m a. m. Tongue has a whitish fur on it and there is a bad taste in my mouth.

6 p. m. Comfortable day so far.

10 p. m. Noticed a very pronounced odor of burning wood between 9 and 10 p. m.; also noticed it yesterday when the doctor was taking my pulse rate. Considerable raising of mucus from throat. Have passed a very comfortable day. This stay in calorimeter much pleasanter than the former; then I felt miserable, now I feel fine and could fast for an indefinite period.

Jan. 31, 1905:

7^h30^m a. m. Heavy sleep from 11 p. m. to 6^h30^m a. m. Tongue is still coated and I have a sweetish-sour taste in throat. Am commencing to feel a little nervous and legs unsteady.

8 a. m. Have removed the rectal thermometer, as it causes considerable irritation.

9^h15^m a. m. Had a desire to defecate. Considerable amount of gas passed off.

12 m. Have smelt an odor of soda or lime 3 or 4 times since I have been in calorimeter. It was very stifling for 30 seconds or so and then passed away.

5^h15^m p. m. Again I can smell an odor of lime.

7^h30^m p. m. Am commencing to feel weak and tired, but I *will* go the limit of 5 days as I intended to.

10 p. m. Passed a very comfortable day, but became weak towards evening.

Feb. 1, 1905:

7^h30^m a. m. Passed the night fairly well, but not as well as the previous night. Awoke a few times during night, but fell asleep again in a few minutes; awoke at 5 a. m. and did not sleep again until 6^h30^m a. m.

8 a. m. My tongue is still coated and I have a sweet taste in my mouth.

9^h15^m a. m. Had a desire to defecate, but unsuccessful. My knees feel weak; muscles feel relaxed.

2 p. m. Have not drunk the usual amount of water, as it is commencing to taste rather badly and I am not thirsty.

8 p. m. My tongue has been swollen all day; noticed it when I awoke this morning.

10 p. m. Feel very much stronger and more comfortable than I did during the day. Could fast 2 more days at least.

Pulse rate—Experiment No. 73.[1]

Time.	Pulse rate.	Time.	Pulse rate.	Time.	Pulse rate.
Jan. 28, 7^h30^ma.m..	66	Jan. 29, 8^h00^mp.m..	50	Jan. 31, 4^h00^mp.m..	49
8 00 a.m..	68	10 00 p.m..	48	6 00 p.m..	54
10 00 a.m..	66	Jan. 30, 8 00 a.m..	62	8 00 p.m..	45
12 00 m....	60	10 00 a.m..	56	10 00 p.m..	49
2 00 p.m..	61	12 00 m....	59	Feb. 1, 7 30 a.m..	63
4 00 p.m..	59	2 00 p.m..	49	8 00 a.m..	53
6 00 p.m..	59	4 00 p.m..	51	10 00 a.m..	46
8 00 p.m..	56	6 00 p.m..	51	12 00 m....	49
10 00 p.m..	50	8 00 p.m..	51	2 00 p.m..	45
Jan. 29, 8 00 a.m..	68	10 00 p.m..	48	4 00 p.m..	46
10 00 a.m..	65	Jan. 31, 7 30 a.m..	54	6 00 p.m..	45
12 00 m....	56	8 00 a.m..	61	8 00 p.m..	48
2 00 p.m..	58	10 00 a.m..	53	10 00 p.m..	49
4 00 p.m..	54	12 00 m....	49		
6 00 p.m..	55	2 00 p.m..	55		

[1] Pulse taken while sitting.

Movements of subject.—Duration, 5 days, from Jan. 28, 7 a. m., to Feb. 2, 7 a. m., 1905.

January 28.

A. M.

7^h00^m rise, urinate.

7 04, 7 11 weigh self, etc.

7 16 fold bed, adjust table, food aperture.

7 20 sit, comb hair.

7 24 write.

7 30 count pulse.

A. M.

8^h00^m count pulse.

8 02 telephone.

8 04 read.

8 20 rise, sit.

8 48 telephone.

9 02 drink.

9 04 rise, food aperture.

9 06 adjust chair, sit, read.

9 08 rise, move about.

A. M.

9^h10^m food aperture.

9 12 jump about.

9 15 defecate.

9 20 sit, write.

9 28 read.

10 00 count pulse.

10 02 food aperture, drink.

11 00 rise, move about, urinate.

January 28.

A. M.

11^h 02^m sit.
11 04 read.
11 22 telephone.
11 24 food aperture.
11 26 sit.
11 30 read.
11 56 telephone.
12 00 count pulse, sit, write.

P. M.

12^h 08^m rise, move about, sit.
12 10 rise, food aperture.
12 12 sit, read.
1 00 rise, move about, urinate.
1 06 read.
2 00 food aperture, count pulse, sit, write.
3 40 drink.
4 00 count pulse, sit, write.
5 01 food aperture.
5 02 sit.
5 04 telephone.
5 06 rise, sit.
5 08 telephone, move about.
5 12 sit.
5 14 stand, telephone.
5 22 rise, food aperture, sit.
5 26 read.
6 00 count pulse.
6 08 rise, move about.
6 12 lean on table, read.
6 38 sit, read.
7 00 food aperture, telephone.
7 02 sit, read.
7 16 food aperture.
7 44 food aperture.
8 00 count pulse.
9 02 rise.
9 20 move about.
10 00 count pulse, write.
10 04 rise.
10 12 sit, read.
11 00 rise, open bed, undress, urinate.
11 06 close curtain.

January 29.

A. M.

4^h 06^m open curtain.
7 00 rise, urinate.
7 04 }
7 10 } weigh self, etc.
7 16 food aperture.

A. M.

7^h 24^m sit.
7 34 write.
7 42 read.
8 00 count pulse.
9 00 rise, move about.
9 02 food aperture.
9 08 move about.
9 10 food aperture.
9 15 defecate.
9 16 move about.
9 20 lean on table.
9 26 sit, read.
10 00 count pulse, write.
10 12 telephone.
10 14 rise, food aperture.
10 18 sit.
10 20 read.
11 24 rise, food aperture, sit.
11 26 rise, food aperture.
11 28 sit.
11 30 rise, lean on table.
11 32 read.
11 44 sit.
12 00 count pulse.

P. M.

1^h 04^m change position, urinate.
1 12 rise, food aperture.
1 14 move about, telephone.
1 18 sit.
1 36 rise, lean on table.
2 00 count pulse, write.
3 04 rise, drink, food aperture, move about.
3 10 food aperture.
3 14 lean on table, read.
3 56 drink.
4 00 count pulse.
5 04 rise, move about.
5 08 lean on table, read.
5 34 telephone, move about.
5 38 telephone, move about.
5 42 stand, doctor count pulse.
5 44 lean on table.
5 52 food aperture.
5 54 move about.
6 06 count pulse, take temperature.
6 10 read, stand.
6 16 move about.
6 18 food aperture.
7 00 rise, urinate.
7 02 stand, read.
7 18 sit, read.
8 00 count pulse.

P. M.

8^h 22^m sit.
8 30 count pulse.
9 00 rise, drink.
9 02 stand, read.
9 26 rise, drink.
9 28 drink.
9 30 sit.
9 32 rise, telephone, food aperture.
9 34 sit.
9 42 rise, food aperture.
9 56 sit.
10 00 rise, sit, count pulse, write.
11 00 rise.
11 02 open bed.
11 06 close curtain, undress, urinate, retire.

January 30.

A. M.

7^h 00^m rise, urinate.
7 04 }
7 14 } weigh self, etc.
7 19 food aperture.
7 22 sit.
7 24 telephone.
7 26 comb hair.
7 28 sit.
7 30 write.
7 42 read.
8 00 count pulse.
8 04 telephone.
8 08 telephone.
8 10 rise, move about, food aperture.
8 12 telephone.
8 18 adjust thermometer, move about.
8 24 read.
9 34 rise, move about.
9 36 defecate.
9 42 move about.
9 44 food aperture.
9 46 sit, write.
9 50 rise, food aperture, sit.
9 54 rise, food aperture.
9 58 telephone.
10 00 count pulse.
10 02 rise, food aperture.
10 04 insert thermometer.
10 06 sit.
10 08 read.
11 18 rise, move about.
11 20 food aperture.
11 22 lean on table.
11 26 food aperture.
11 30 lean on table.

January 30.

A. M.
$11^h 40^m$ sit.
11 44 recline, write.
11 54 telephone, rise, food aperture.
11 58 sit, read.
12 00 count pulse.

P. M.
$1^h 02^m$ rise, move about, urinate.
1 08 lean on table, read.
1 12 drink, read.
1 14 stand, read.
1 44 sit, read.
2 00 count pulse.
2 06 rise, food aperture.
2 08 lean on table, telephone.
2 12 read.
2 18 food aperture.
2 22 sit, read.
3 02 move about.
3 12 sit, read.
3 54 rise, food aperture, move about.
3 56 sit.
4 00 count pulse.
4 28 move about, sit.
5 00 rise, move about.
5 30 rise, move about, food aperture.
5 36 food aperture.
5 42 sit.
5 46 telephone.
5 48 stand.
5 50 rise, sit.
5 52 doctor count pulse.
5 56 sit.
6 00 count pulse.
6 02 read.
7 00 rise, urinate.
7 02 stand, sit.
8 00 count pulse.
8 04 telephone.
8 10 telephone, food aperture.
8 18 sit.
8 28 telephone.
8 36 sit.
10 00 count pulse, write.
11 00 rise.
11 08 undress, urinate, retire.

January 31.

A. M.
$7^h 00^m$ rise, urinate.
7 04 } weigh self, etc.
7 10 }
7 14 dress.
7 18 sit, move about.
$7^h 19^m$ food aperture.
7 22 sit.
7 30 count pulse, write.
7 36 sit.
8 04 telephone.
8 06 read.
8 52 drink.
9 02 rise, food aperture.
9 04 food aperture.
9 06 sit.
9 22 rise, move about, attempt to defecate.
9 32 sit, read.
10 00 count pulse.
10 20 telephone.
10 22 rise, food aperture.
10 24 sit.
11 04 stand, move about, sit, write.
12 00 count pulse.

P. M.
$12^h 20^m$ rise, move about.
12 22 food aperture.
12 26 stand, move about, sit.
12 30 rise, food aperture.
12 32 sit, read.
1 00 rise, urinate.
1 04 telephone.
1 06 move about, stand.
1 12 sit, write.
1 16 sit, read.
2 00 count pulse.
2 02 rise, food aperture, sit.
2 04 food aperture.
2 06 lean on table.
2 14 telephone.
2 16 move about, telephone.
2 20 sit, read.
3 04 rise, move about, urinate.
3 06 lean on table, read.
3 10 food aperture.
3 12 read, stand.
3 16 lean on table.
3 20 telephone.
3 24 food aperture.
3 38 sit, read.
4 00 count pulse.
5 04 rise, move about.
5 10 lean on table, read.
5 28 telephone.
5 30 stand.
5 32 move about.
5 36 move about, stand, doctor count pulse.
5 42 lean on table, read.

P. M.
$5^h 44^m$ food aperture.
5 46 take temperature.
6 00 count pulse.
6 02 move about.
6 04 stand, read.
6 14 sit, read.
7 00 rise, urinate.
7 02 urinate, food aperture.
7 04 lean on table, read.
8 00 count pulse.
10 00 count pulse.
10 04 rise.
10 08 sit.
11 00 rise, undress, urinate, retire.

February 1.

A. M.
$7^h 00^m$ rise, urinate.
7 04 } weigh self, etc.
7 11 }
7 20 food aperture.
7 24 sit, comb hair.
7 30 write, count pulse.
8 00 count pulse.
9 00 rise, move about, food aperture.
9 06 sit.
9 15 attempt to defecate.
9 18 rise, food aperture.
9 28 lean on table, read.
9 30 write.
9 36 move about.
9 42 sit, read.
10 00 count pulse.
10 32 move about.
11 04 rise, lean on table.
11 16 move about.
11 18 telephone.
11 22 read.
12 00 count pulse.

P. M.
$1^h 02^m$ rise, move about, urinate.
1 06 lean on table.
1 22 food aperture.
1 24 move about, sit, read.
2 00 count pulse.
4 00 count pulse.
5 06 rise, move.
5 10 stand, read.
5 42 telephone.
5 44 stand.
5 46 move about.
5 48 stand, doctor count pulse.
5 54 sit.
5 56 read.

February 1

P. M.		P. M.		P. M.	
6h 00m	count pulse.	7h 06m	stand, write.	10h 00m	count pulse, write.
6 02	rise, food aperture.	7 35	food aperture.	10 08	rise.
6 04	take temperature.	7 40	sit, read.	10 24	lean on table.
7 00	food aperture, urinate.	8 00	count pulse.	11 00	rise, urinate, close curtain, undress, retire.
		8 08	food aperture.		
		8 28	rise, move about.		

Drinking-water.—Water was furnished as desired and consumed between 7 a. m. and 11 p. m. The quantities consumed per day and approximate amounts per period are given in table 93. It will be seen that relatively large, but often varied, amounts of water were consumed on all days of the experiment. Thus during both the second and the third day the subject consumed nearly 3 liters of water while on the last day the amount drunk was but a little more than a liter. This marked variation in the amount of water consumed on different days is but one indication of the noticeable differences in bodily and mental states exhibited by this subject. In all of his experiments there was frequent complaint concerning the water, although in this and subsequent experiments, at the subject's request, distilled water was furnished.

TABLE 93.—*Record of water consumed*[1]—*Metabolism experiment No. 73.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a.m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	Total for day.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 28–29....	379.80	462.10	159.53	159.53	159.54	465.90	147.95	147.95	2082.30
Jan. 29–30....	421.40	406.40	353.70	381.50	389.50	199.90	199.90	394.60	2746.90
Jan. 30–31....	396.10	401.50	398.10	396.30	379.90	395.80	197.75	197.75	2763.20
Jan. 31–Feb.1.	396.90	191.50	386.60	325.56	130.47	130.47	196.95	196.95	1955.40
Feb. 1–2......	398.60	147.45	....	147.45	....	....	191.20	191.20	1075.90

[1] Period during which water was consumed was assumed in some instances.

URINE.

The urine was collected in 4 periods, as is customary. The weight, specific gravity, reaction, nitrogen, creatinine, and, with the exception of the first day, the phosphoric acid were determined for each period. The results are recorded in table 94. The specific gravity in this and all subsequent experiments was taken by means of the Westphal balance. The creatinine and phosphoric acid were determined by Prof. L. B. Mendel, of Yale University. The usual check on the accuracy of the analytical work was made by comparing the total amounts of nitrogen, creatinine, and phosphoric acid as determined by periods with those determined on the composite samples. In the case of nitrogen and phosphoric acid the agreement was extremely satisfactory with the single exception of the phosphoric acid for the fourth day of the experiment.

Weight, composition, and heat of combustion of urine.—In addition to the determinations given in table 94 in the samples from the different periods, each day's composite sample was analyzed much more completely and the

elements nitrogen, carbon, hydrogen, phosphorus, sulphur, and chlorine, as well as the water, total solids, ash, total creatinine, and uric acid, were deter-

TABLE 94.—*Determinations in urine per period and per day—Metabolism experiment No. 73.*

Date and period.	(*a*) Amount.	(*b*) Specific gravity.	(*c*) Volume (*a*+*b*).	(*d*) Reaction.	(*e*) Nitrogen.	(*f*) Phosphoric acid by titration (P_2O_5).	(*g*) Total creatinine.
1905. Jan. 28–29:	*Grams.*		*c. c.*		*Grams.*	*Grams.*	*Grams.*
7 a.m. to 1 p.m...	875.6	1.0053	871	Neutral...	2.58	....	0.344
1 p.m. 7 p.m...	552.6	1.0056	549	Acid......	2.56	....	.336
7 p.m. 11 p.m...	235.9	1.0077	235	....do.....	1.52	....	.211
11 p.m. 7 a.m...	600.2	1.0069	597	....do.....	3.63	....	.464
Total............	2264.3	....	2252	....	10.29	....	1.355
Total by composite.	2264.3	1.0057	2252	Acid......	10.24	....	1.250
Jan. 29–30:							
7 a.m. to 1 p.m...	817.4	1.0030	815	Acid......	3.13	0.505	.400
1 p.m. 7 p.m...	939.2	1.0028	937	....do.....	3.23	.618	.421
7 p.m. 11 p.m...	414.0	1.0037	412	....do.....	1.87	.313	.172
11 p.m. 7 a.m...	796.2	1.0030	794	....do.....	3.74	.610	.361
Total............	2966.8	....	2958	....	11.97	2.046	1.354
Total by composite.	2966.8	1.0032	2958	Acid......	11.86	2.045	1.200
Jan. 30–31:							
7 a.m. to 1 p.m...	636.1	1.0051	633	Acid......	3.13	.490	.270
1 p.m. 7 p.m...	890.6	1.0024	888	....do.....	2.72	.507	.151
7 p.m. 11 p.m...	643.5	1.0031	642	....do.....	2.55	.418	.192
11 p.m. 7 a.m...	565.0	1.0047	562	....do.....	3.09	.522	.288
Total............	2735.2	....	2725	....	11.54	1.937	.901
Total by composite.	2735.2	1.0036	2725	Acid......	11.54	1.916	.871
Jan. 31–Feb. 1.......							
7 a.m. to 1 p.m...	608.5	1.0050	605	Acid......	3.10	.518	.210
1 p.m. 7 p.m...	768.0	1.0036	765	....do.....	2.92	.690	.202
7 p.m. 11 p.m...	202.4	1.0084	201	....do.....	1.52	.327	.106
11 p.m. 7 a.m...	385.2	1.0079	382	....do.....	2.85	.367	.223
Total............	1964.1	....	1953	....	10.39	1.902	.741
Total by composite.	1964.1	1.0056	1953	Acid......	10.33	2.107	.791
Feb. 1–2:							
7 a.m. to 1 p.m...	454.7	1.0074	451	Acid......	3.14	.575	.308
1 p.m. 7 p.m...	244.0	1.0147	241	....do.....	2.61	.692	.278
7 p.m. 11 p.m...	108.2	1.0157	107	....do.....	1.36	.325	.173
11 p.m. 7 a.m...	230.9	1.0153	227	....do.....	2.87	.595	.388
Total............	1037.8	....	1026	....	9.98	2.187	1.147
Total by composite.	1037.8	1.0119	1026	Acid.....	9.93	2.178	1.110
Total, 5 days......	10,968.2	....	10,914	....	54.17	....	....

mined. From the percentages thus obtained and the weight of urine, the quantities of elements and compounds eliminated were computed. The results are recorded in table 95. The determinations of the phosphoric acid by titration, total creatinine, uric acid and chlorine were made through the kindness

of Professor Mendel who was assisted in his analyses by Mr. O. E. Closson. The urine voided during the last 3 days of the experiment was of such a character that only an approximate estimate of the amount of uric acid based upon the maximum solubility of ammonium urate could be made.

The chlorine determinations were made according to the Volhard method. In line *q* of the table they are expressed as the element chlorine, but to facilitate a comparison with the output in other experiments the chlorine is calculated as sodium chloride and it is so recorded in line *r*.

TABLE 95.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 73.*

	Jan. 28-29.	Jan. 29-30.	Jan. 30-31.	Jan. 31-Feb. 1.	Feb. 1-2.	Total for 5 days.
(*a*) Weight...........grams.	2264.8	2966.8	2735.2	1964.1	1037.8	10,968.2
(*b*) Water.............do...	2225.81	2928.23	2698.27	1928.35	1001.89	10,782.55
(*c*) Solids, *a*—*b*.........do...	38.49	38.57	36.93	35.75	35.91	185.65
(*d*) Ash...............do...	9.96	6.23	5.74	6.09	6.02	34.04
(*e*) Organic matter, *c*—*d*.do...	28.53	32.34	31.19	29.66	29.89	151.61
(*f*) Nitrogen...........do...	10.29	11.97	11.54	10.39	9.98	54.17
(*g*) Carbon.............do...	7.47	8.31	7.93	7.66	7.89	39.26
(*h*) Hydrogen in organic matter...........do...	1.81	2.08	2.19	1.96	1.97	10.01
(*i*) Oxygen (by difference) in organic matter, *e*—(*f*+*g*+*h*)......do...	8.96	9.98	9.53	9.65	10.05	48.17
(*j*) Phosphorus.........do...	1.024	.830	.846	.942	.931	4.573
Phosphoric acid (P_2O_5):						
(*k*) By fusion........do...	2.345	1.904	1.938	2.159	2.134	10.480
(*l*) By titration......do...	....	2.045	1.916	2.107	2.178	....
(*m*) Sulphur............do...	.644	.700	.712	.693	.707	3.456
(*n*) Sulphur trioxide (SO_3).............do...	1.608	1.747	1.774	1.729	1.765	8.623
(*o*) Total creatinine....do...	1.250	1.200	.871	.791	1.110	5.222
(*p*) Uric acid....... ...do...	.172	.122	[1].082	[1].059	[1].054	.489
(*q*) Chlorine............do...	1.630	.466	.159	.356	.408	3.019
(*r*) Sodium chloride....do...	2.690	.769	.262	.587	.674	4.982
(*s*) Heat of combustion.... ......calories.	86	98	96	92	92	464

[1] Approximate. The character of the sample precluded an accurate estimation.

Especially noticeable are the large volumes of urine excreted on the first 4 days of the experiment. On the second day there were nearly 3 liters excreted, while on the last day about 1 liter was passed.

The total amounts of phosphoric acid in the urine as determined both by titration and by fusion are here recorded. The data are of value for discussing the possibility of the presence of so-called organic phosphorus in the urine.[a]

The appearance of the significant paper by Dr. Folin[b] on the relation of creatinine to metabolism led to the determination of creatinine in the urines from this and the succeeding fasting experiments here reported.

[a] For discussion of this subject, see "Organic Phosphorus in Urine," Part 3, of this report.

[b] Amer. Jour. Physiol. (1905), 13, p. 66.

TABLE 96.—*Record of water of respiration and perspiration—Metabolism experiment No. 73.*

Date.	Period.	(a) Total am'nt of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905.	Preliminary:	*Grams.*	*Grams.*
Jan. 28....	1 a.m.........	48.4	....
	1 a.m. to 3 a.m.	44.5	71.9
	3 a.m. 5 a.m.	39.0	76.0
	5 a.m. 7 a.m.	37.7	67.1
	Total......	....	215.0
Jan. 28–29.	7 a.m. to 9 a.m.	38.7	72.9
	9 a.m. 11 a.m.	37.4	67.6
	11 a.m. 1 p.m.	35.0	59.0
	1 p.m. 3 p.m.	34.0	56.4
	3 p.m. 5 p.m.	33.7	54.6
	5 p.m. 7 p.m.	32.9	58.6
	7 p.m. 9 p.m.	29.2	52.9
	9 p.m. 11 p.m.	27.2	51.4
	11 p.m. 1 a.m.	29.2	54.2
	1 a.m. 3 a.m.	28.8	53.6
	3 a.m. 5 a.m.	27.7	51.3
	5 a.m. 7 a.m.	27.2	51.7
	Total......	....	684.2
Jan. 29–30.	7 a.m. to 9 a.m.	31.4	59.0
	9 a.m. 11 a.m.	31.9	67.3
	11 a.m. 1 p.m.	30.2	54.9
	1 p.m. 3 p.m.	28.1	52.3
	3 p.m. 5 p.m.	27.8	52.6
	5 p.m. 7 p.m.	28.3	55.2
	7 p.m. 9 p.m.	27.0	53.5
	9 p.m. 11 p.m.	25.7	51.4
	11 p.m. 1 a.m.	25.1	48.1
	1 a.m. 3 a.m.	25.4	50.2
	3 a.m. 5 a.m.	25.2	47.6
	5 a.m. 7 a.m.	23.3	44.0
	Total......	....	636.1
Jan. 30–31.	7 a.m. to 9 a.m.	30.0	59.0
	9 a.m. 11 a.m.	29.3	54.8
	11 a.m. 1 p.m.	28.1	52.4
	1 p.m. 3 p.m.	27.5	52.2
1905.		*Grams.*	*Grams.*
Jan. 30–31.	3 p.m. to 5 p.m.	28.2	52.4
	5 p.m. 7 p.m.	27.6	51.5
	7 p.m. 9 p.m.	28.6	52.7
	9 p.m. 11 p.m.	25.3	46.5
	11 p.m. 1 a.m.	25.7	46.6
	1 a.m. 3 a.m.	23.4	42.7
	3 a.m. 5 a.m.	25.7	47.5
	5 a.m. 7 a.m.	24.4	44.0
	Total......	....	602.3
Jan. 31 to Feb. 1..	7 a.m. to 9 a.m.	28.5	52.5
	9 a.m. 11 a.m.	25.9	49.7
	11 a.m. 1 p.m.	27.9	52.2
	1 p.m. 3 p.m.	26.0	48.1
	3 p.m. 5 p.m.	24.7	45.8
	5 p.m. 7 p.m.	25.4	46.6
	7 p.m. 9 p.m.	27.0	50.3
	9 p.m. 11 p.m.	23.7	46.2
	11 p.m. 1 a.m.	25.0	46.6
	1 a.m. 3 a.m.	23.8	44.2
	3 a.m. 5 a.m.	24.0	43.9
	5 a.m. 7 a.m.	22.6	43.1
	Total......	....	569.2
Feb. 1–2..	7 a.m. to 9 a.m.	27.3	51.0
	9 a.m. 11 a.m.	23.9	47.2
	11 a.m. 1 p.m.	23.8	44.1
	1 p.m. 3 p.m.	23.3	45.4
	3 p.m. 5 p.m.	23.1	40.2
	5 p.m. 7 p.m.	23.8	46.3
	7 p.m. 9 p.m.	27.6	48.2
	9 p.m. 11 p.m.	25.5	49.9
	11 p.m. 1 a.m.	25.0	41.7
	1 a.m. 3 a.m.	23.0	43.2
	3 a.m. 5 a.m.	24.7	41.4
	5 a.m. 7 a.m.	23.4	44.7
	Total......	....	543.3

[1] Allowance has been made for loss of water from absorbers, chair, bedding, and miscellaneous articles as follows: Jan. 28-29, 92.60 grams; Jan. 29-30, 52.10 grams; Jan. 30-31, 37.07 grams; Jan. 31-Feb. 1, 30.85 grams; Feb. 1-2, 20.07 grams.

TABLE 97.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 73.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1905.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 28.......	1 a.m...........	27.9	....	915.1	....
	1 a.m. to 3 a.m...	26.3	45.0	917.1	35.8
	3 a.m. 5 a.m...	27.3	56.2	921.9	37.0
	5 a.m. 7 a.m...	28.8	52.5	923.0	38.3
	Total..........	....	153.7	....	111.1
Jan. 28–29....	7 a.m. to 9 a.m...	30.2	68.2	920.5	61.6
	9 a.m. 11 a.m...	30.4	62.7	918.7	50.4
	11 a.m. 1 p.m...	31.0	57.7	912.3	48.7
	1 p.m. 3 p.m...	30.0	52.6	925.3	43.7
	3 p.m. 5 p.m...	28.7	52.2	935.7	46.8
	5 p.m. 7 p.m...	28.3	55.7	948.1	50.8
	7 p.m. 9 p.m...	21.7	45.1	959.0	42.6
	9 p.m. 11 p.m...	23.8	50.2	970.9	48.0
	11 p.m. 1 a.m...	20.4	42.7	970.5	36.1
	1 a.m. 3 a.m...	17.8	37.5	975.0	40.1
	3 a.m. 5 a.m...	19.1	41.8	982.2	36.2
	5 a.m. 7 a.m...	19.1	42.5	989.5	39.2
	Total	....	608.9	....	544.2
Jan. 29–30....	7 a.m. to 9 a.m...	27.0	62.6	987.8	63.7
	9 a.m. 11 a.m...	27.1	56.8	987.8	55.5
	11 a.m. 1 p.m...	26.3	48.8	980.9	47.6
	1 p.m. 3 p.m...	25.8	49.6	985.4	47.2
	3 p.m. 5 p.m...	23.1	47.4	984.1	51.8
	5 p.m. 7 p.m...	24.4	53.3	984.6	49.1
	7 p.m. 9 p.m...	21.2	46.1	989.1	45.6
	9 p.m. 11 p.m...	21.6	47.2	989.2	48.7
	11 p.m. 1 a.m...	17.2	36.8	990.3	28.4
	1 a.m. 3 a.m...	18.0	37.3	993.8	40.7
	3 a.m. 5 a.m...	18.5	37.3	987.5	37.4
	5 a.m. 7 a.m...	17.5	36.8	993.6	32.2
	Total..........	....	560.0	....	547.9
Jan. 30–31....	7 a.m. to 9 a.m...	27.3	64.2	990.3	68.2
	9 a.m. 11 a.m...	27.6	52.2	991.3	49.5
	11 a.m. 1 p.m...	25.2	50.5	984.7	49.0
	1 p.m. 3 p.m...	28.3	50.7	977.3	50.1
	3 p.m. 5 p.m...	25.6	50.6	982.0	48.7
	5 p.m. 7 p.m...	24.0	49.9	992.2	46.2
	7 p.m. 9 p.m...	22.6	44.9	994.1	43.4
	9 p.m. 11 p.m...	21.0	40.9	998.8	37.3
	11 p.m. 1 a.m...	17.2	36.5	1004.2	33.7
	1 a.m. 3 a.m...	17.3	33.2	1003.8	33.0
	3 a.m. 5 a.m...	22.0	40.2	998.2	40.2
	5 a.m. 7 a.m...	19.2	27.9	1003.4	33.7
	Total..........	....	541.7	....	533.0

TABLE 97.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 31–Feb. 1.	7 a.m. to 9 a.m...	25.6	56.0	1001.3	55.1
	9 a.m. 11 a.m...	26.5	52.7	992.0	53.6
	11 a.m. 1 p.m...	25.6	50.2	984.6	49.5
	1 p.m. 3 p.m...	27.1	45.4	974.6	41.6
	3 p.m. 5 p.m...	22.3	43.1	978.9	43.3
	5 p.m. 7 p.m...	24.0	47.0	975.5	43.3
	7 p.m. 9 p.m...	23.8	46.2	972.4	42.9
	9 p.m. 11 p.m...	20.7	38.9	978.7	38.1
	11 p.m. 1 a.m...	18.3	34.6	972.3	30.3
	1 a.m. 3 a.m...	19.6	33.1	970.0	36.3
	3 a.m. 5 a.m...	18.5	32.7	966.5	32.7
	5 a.m. 7 a.m...	19.7	35.3	968.3	36.0
	Total..........	....	515.2	....	502.7
Feb. 1–2......	7 a.m. to 9 a.m...	26.4	53.5	963.7	52.3
	9 a.m. 11 a.m...	25.0	43.0	960.2	44.6
	11 a.m. 1 p.m...	23.7	42.1	951.5	42.0
	1 p.m. 3 p.m...	25.9	42.9	942 7	41.3
	3 p.m. 5 p.m...	22.4	40.7	941.4	38.5
	5 p.m. 7 p.m...	23.1	43.6	939.8	46.8
	7 p.m. 9 p.m...	25.7	45.2	928.0	44.2
	9 p.m. 11 p.m...	22.8	39.8	927.1	41.6
	11 p.m. 1 a.m...	19.0	31.8	623.2	28.1
	1 a.m. 3 a.m...	17.5	30.0	928.6	33.7
	3 a.m. 5 a.m...	20.5	34.6	924.8	36.1
	5 a.m. 7 a.m...	20.9	34.8	924.4	36.3
	Total..........	....	482.0	....	485.5

ELIMINATION OF WATER-VAPOR.

The determination of water of respiration and perspiration was made in 2-hour periods. The data are given in table 96, page 143. During the progress of the experiment the total amount of water-vapor residual inside the chamber gradually grew less and as a result of the decreased relative humidity there was a constant loss of water from articles in the chamber. The daily amounts of this loss are recorded at the foot of the table.

The total water of respiration and perspiration gradually diminished from 684.22 grams on the first day to 543.34 grams on the fifth day.

Cutaneous excretion of nitrogenous material.—The bath water used by this subject after coming out of the calorimeter at the end of this series of experiments, i. e., Nos. 73 and 74, contained 0.3822 gram of nitrogen, and the water used in extracting his underclothes yielded 0.2659 gram, a total of 0.6481 gram, or 0.081 gram per day.

TABLE 98.—*Elements katabolized in body—Metabolism experiment No. 73.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Jan. 28, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.....	544.24	....	....	....	544.24	....
Outgo:						
Water in urine..........	2225.81	....	....	249.07	1976.74	....
Solids in urine..........	38.49	10.29	7.47	1.81	8.96	9.96
Water of respiration[1].....	684.22	....	....	76.56	607.66	....
Carbon dioxide...........	608.87	....	166.07	....	442.80	....
Total..................	3557.39	10.29	173.54	327.44	3036.16	9.96
Loss...................	3013.15	10.29	173.54	327.44	2491.92	9.96
Second day, Jan. 29, 1905.						
Income: Oxygen from air.....	547.86	....	....	....	547.86	....
Outgo:						
Water in urine...........	2928.23	....	....	327.67	2600.56	....
Solids in urine...........	38.57	11.97	8.31	2.08	9.98	6.23
Water of respiration[1]......	636.05	....	....	71.17	564.88	....
Carbon dioxide...........	560.02	....	152.72	....	407.30	....
Total..................	4162.87	11.97	161.03	400.92	3582.72	6.23
Loss...................	3615.01	11.97	161.03	400.92	3034.86	6.23
Third day, Jan. 30, 1905.						
Income: Oxygen from air.....	533.04	....	....	....	533.04	....
Outgo:						
Water in urine...........	2698.27	....	....	301.94	2396.33	....
Solids in urine...........	36.93	11.54	7.93	2.19	9.53	5.74
Water of respiration[1]......	602.31	....	....	67.40	534.91	....
Carbon dioxide...........	541.67	....	147.74	....	393.93	....
Total..................	3879.18	11.54	155.67	371.53	3334.70	5.74
Loss...................	3346.14	11.54	155.67	371.53	2801.66	5.74
Fourth day, Jan. 31, 1905.						
Income: Oxygen from air.....	502.68	....	....	....	502.68	....
Outgo:						
Water in urine...........	1928.35	....	....	215.78	1712.57	....
Solids in urine...........	35.75	10.39	7.66	1.96	9.65	6.09
Water of respiration[1]......	569.17	....	....	63.69	505.48	....
Carbon dioxide...........	515.22	....	140.51	....	374.71	....
Total..................	3048.49	10.39	148.17	281.43	2602.41	6.09
Loss...................	2545.81	10.39	148.17	281.43	2099.73	6.09
Fifth day, Feb. 1, 1905.						
Income: Oxygen from air.....	485.54	....	....	....	485.54	....
Outgo:						
Water in urine...........	1001.89	....	....	112.11	889.78	....
Solids in urine...........	35.91	9.98	7.89	1.97	10.05	6.02
Water of respiration[1]......	543.34	....	....	60.80	482.54	....
Carbon dioxide...........	482.00	....	131.47	....	350.53	....
Total..................	2063.14	9.98	139.36	174.88	1732.90	6.02
Loss...................	1577.60	9.98	139.36	174.88	1247.36	6.02

[1] Includes also water of perspiration.

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The quantities of carbon dioxide and oxygen residual in the chamber at the end of each experimental period as well as the total amounts of carbon dioxide exhaled and oxygen consumed by the subject are given in table 97, page 144. Fluctuations are noted in the residual amounts of carbon dioxide and oxygen as in the earlier experiments.

The amount of carbon dioxide excreted was greatest on the first day and diminished with considerable regularity to the end of the experiment. On the other hand, the daily amounts of oxygen consumed remained nearly constant for the first 2 days, after which there was a gradual diminution from day to day.

TABLE 99.—*Elements and materials katabolized in body—Metabolism experiment No. 73.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1905.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Jan. 28–29....	10.29	173.54	327.44	2,491.92	2,700.44	61.74	106.63	135.32	9.96
Jan. 29–30....	11.97	161.03	400.92	3,034.86	3,368.29	71.82	151.72	18.05	6.23
Jan. 30–31....	11.54	155.67	371.53	2,801.66	3,112.16	69.24	152.62	7.44	5.74
Jan. 31–Feb. 1.	10.39	148.17	281.43	2,099.73	2,317.55	62.34	139.15	21.63	6.09
Feb. 1–2......	9.98	139.36	174.88	1,247.36	1,375.38	59.88	148.07	[1]10.84	6.02
Total, 5 days.	54.17	777.77	1556.20	11,675.53	12,873.82	325.02	698.19	171.60	34.04

[1] Glycogen gained.

ELEMENTS KATABOLIZED IN THE BODY.

The elements katabolized in the body, obtained by the methods previously described, are given in table 98. The apparently excessive losses of total weight, hydrogen, and oxygen are partly compensated by the large amounts of water consumed.

Elements and materials katabolized in the body.—A summary of the losses of the elements and the compounds computed therefrom by means of formulæ previously recorded is given in table 99. As in the preceding table, there is a very large apparent loss of hydrogen, oxygen, and water. The loss in protein averages 65 grams per day.

In common with the other fasting experiments, there is a very large loss of glycogen during the first 24 hours of the fast and lesser losses on the 3 days following, but on the fifth day there is apparently a gain of 10.84 grams. The probability of a gain of glycogen after 4 consecutive days of fasting demands special consideration, but discussion of the point is deferred until later (Part 3, Materials Katabolized, Glycogen) in the report.

Balance of water.—In table 100, showing the distribution of intake and output of water, the results are obtained as explained earlier in this publication. Allowance has not been made in columns *d* and *f*, however, for water of feces passed on the first 3 days of the experiment for the reason explained in the discussion of table 73, page 120.

The data below show that the actual loss of water to the body was very much less than the apparent loss shown in table 99. The water of oxidation of organic hydrogen is not materially different in amount from that found in the previous fasting experiments.

TABLE 100.—*Distribution of intake and outgo of water—Metabolism experiment No. 73.*

Date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c−d).
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.[1]	(e) Intake in drink.	(f) Loss of preformed water[1] (d−e).	
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 28–29	2,225.8	684.2	2,910.0	2,700.4	2,082.3	618.1	209.6
Jan. 29–30	2,928.2	636.1	3,564.3	3,368.3	2,746.9	621.4	196.0
Jan. 30–31	2,698.3	602.3	3,300.6	3,112.2	2,763.2	349.0	188.4
Jan. 31–Feb. 1	1,928.3	569.2	2,497.5	2,317.5	1,955.4	362.1	180.0
Feb. 1–2	1,001.9	543.3	1,545.2	1,375.4	1,075.9	299.5	169.8
Total, 5 days	10,782.5	3035.1	13,817.6	12,873.8	10,623.7	2250.1	943.8
Average per day	2,156.5	607.0	2,763.5	2,574.7	2,124.7	450.0	188.8

[1] Does not include water of feces. Feces were passed on the first three days of the experiment only.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

The subject was weighed as usual each morning throughout the experiment and in table 101 a comparison of the changes in body-weight with the balance of income and outgo is given. The income consists of water and oxygen consumed while the outgo includes the urine, feces, carbon dioxide, and water of respiration and perspiration.

Before the fasting period began the subject took a gelatin capsule filled with lampblack. Feces were passed the first 3 days of the experiment in the following amounts: First day, 71.60 grams; second day, 87 grams; and the third day, 51.10 grams, but as they contained no lampblack they undoubtedly resulted from the food consumed before the fast. In making the balance of income and outgo, however, the feces have in effect been restored to the body of the subject, and the losses shown by the scale have been correspondingly reduced.

In comparing the losses in body material with the losses in body-weight, it is seen that aside from the discrepancy of over 100 grams on the first day, the agreement is quite satisfactory. It is to be observed that on each of the last 4 days the loss of body-weight is slightly greater than the loss of body material computed from the income and outgo.

OUTPUT OF HEAT.

The summarized data for the total heat production per 2-hour period are given in table 102. The total heat production is greatest on the first day and gradually diminishes throughout the experiment.

TABLE 101.—*Comparison of changes in body weight with balance of income and outgo—Metabolism experiment No. 73.*

	Jan. 28-29.	Jan. 29-30.	Jan. 30-31.	Jan. 31-Feb. 1.	Feb. 1-2.	Total for 5 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Water consumed......	2082.30	2746.90	2763.20	1955.40	1075.90	10,623.70	2124.74
(*b*) Oxygen..............	544.24	547.86	533.04	502.68	485.54	2,613.36	522.67
(*c*) Total (*a*+*b*)..........	2626.54	3294.76	3296.24	2458.08	1561.44	13,237.06	2647.41
Outgo:							
(*d*) Urine[1]...............	2615.50	2770.80	2966.40	2143.90	1192.10	11,688.70	2337.74
(*e*) Feces[2]...............	71.60	87.00	51.10	....	....	209.70	41.94
(*f*) Carbon dioxide........	608.87	560.02	541.67	515.22	482.00	2,707.78	541.56
(*g*) Water of respiration and perspiration.....	684.22	636.05	602.31	569.17	543.34	3,035.09	607.02
(*h*) Total (*d*+*f*+*g*).......	3908.59	3966.87	4110.38	3228.29	2217.44	17,431.57	3486.31
(*i*) Loss of body material (*h*−*c*)...............	1282.05	672.11	814.14	770.21	656.00	4,194.51	838.90
(*j*) Loss of body weight..	1168.00	686.00	836.00	779.00	668.00	4,137.00	827.40

[1] The data in this column should not be confounded with urine data in other tables. See explanation, p. 66.
[2] Not included in the total outgo. See p. 148.

BALANCE OF ENERGY.

Allowing for the energy of the incompletely oxidized products of protein katabolism, the total energy derived from all sources may be computed and compared with the total heat production. This comparison is shown in table 103.

On comparing the total energy derived from different sources with the total heat production it is seen that on the first day the computed energy is 19 calories, or 1.0 per cent, smaller than the total heat production. The largest discrepancy appears on the last day when the total as derived from all sources is 66 calories, i. e., 4.3 per cent greater than the total heat production. In these computations it should be borne in mind that the energy from the body glycogen stored on the last day has been deducted from and not added to the energy from the body protein and fat inasmuch as it represents energy stored and not liberated. The largest discrepancy appears on the day on which the smallest total heat production is measured.

TABLE 102.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 73.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Jan. 28.............	1 a.m. to 3 a.m....	96.1	42.6	[2]— 3.6	[2]135.1
	3 a.m. 5 a.m....	88.7	44.9	[2]	[2]133.6
	5 a.m. 7 a.m....	58.6	39.8	[2]	[2]128.4
	Total............	273.4	127.3	[2]— 3.6	[2]397.1
Jan. 28-29..........	7 a.m. to 9 a.m....	178.4	47.7	—26.5	199.6
	9 a.m. 11 a.m....	138.3	44.6	+ 1.2	184.1
	11 a.m. 1 p.m....	128.1	39.5	+11.7	179.3
	1 p.m. 3 p.m....	118.2	38.0	— 1.7	154.5
	3 p.m. 5 p.m ...	130.4	36.9	—10.6	156.7
	5 p.m. 7 p.m....	128.4	39.2	+15.8	183.4
	7 p.m. 9 p.m....	126.7	35.9	— 5.9	156.7
	9 p.m. 11 p.m....	129.6	35.0	—22.6	142.0
	11 p.m. 1 a.m....	59.6	36.7	+14.8	111.1
	1 a.m. 3 a.m....	70.0	36.3	+ 9.3	115.6
	3 a.m. 5 a.m....	94.9	34.9	+14.4	144.2
	5 a.m. 7 a.m....	87.5	35.1	+15.8	138.4
	Total............	1390.1	459.8	+15.7	1865.6
Jan. 29-30..........	7 a.m. to 9 a.m....	165.0	37.5	—19.6	182.9
	9 a.m. 11 a.m....	132.8	42.4	+15.5	190.7
	11 a.m. 1 p.m....	128.3	35.0	— 0.7	162.6
	1 p.m. 3 p.m....	119.5	33.5	+ 5.1	158.1
	3 p.m. 5 p.m....	112.6	33.7	+ 3.4	149.7
	5 p.m. 7 p.m....	137.6	35.2	+ 5.8	178.6
	7 p.m. 9 p.m....	129.3	34.3	—12.4	151.2
	9 p.m. 11 p.m....	123.6	33.0	—15.2	141.4
	11 p.m. 1 a.m....	51.5	31.1	+18.5	101.1
	1 a.m. 3 a.m....	77.5	32.2	+ 4.4	114.1
	3 a.m. 5 a.m....	81.1	30.8	+24.9	136.8
	5 a.m. 7 a.m....	89.0	28.6	+ 5.9	123.5
	Total............	1347.8	407.4	+35.6	1790.8
Jan. 30-31..........	7 a.m. to 9 a.m....	165.8	36.8	—25.2	177.4
	9 a.m. 11 a.m....	133.5	34.3	+ 6.5	174.3
	11 a.m. 1 p.m....	111.3	32.8	+14.3	158.4
	1 p.m. 3 p.m....	121.3	32.7	+ 7.3	161.3
	3 p.m. 5 p.m....	134.5	32.9	— 0.9	166.5
	5 p.m. 7 p.m....	128.9	32.3	+ 8.3	169.5
	7 p.m. 9 p.m....	129.4	33.0	—17.5	144.9
	9 p.m. 11 p.m....	113.6	29.4	+ 0.5	143.5
	11 p.m. 1 a.m....	63.2	29.4	— 0.0	92.6
	1 a.m. 3 a.m....	76.6	27.1	+ 3.1	106.8
	3 a.m. 5 a.m....	68.5	29.9	+22.9	121.3
	5 a.m. 7 a.m....	80.5	27.9	+14.2	122.6
	Total............	1327.1	378.5	+33.5	1739.1

[1] See pp. 42-49.
[2] Not corrected for change in body temperature and weight.

TABLE 102.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Jan. 31–Feb. 1	7 a.m. to 9 a.m.	149.1	32.6	−23.3	158.4
	9 a.m. 11 a.m.	123.1	30.9	+ 7.5	161.5
	11 a.m. 1 p.m.	128.1	32.4	+ 7.6	168.1
	1 p.m. 3 p.m.	122.1	30.0	+ 4.5	156.6
	3 p.m. 5 p.m.	115.6	28.6	− 3.4	140.8
	5 p.m. 7 p.m.	126.9	29.1	− 0.8	155.2
	7 p.m. 9 p.m.	117.3	31.3	− 5.5	143.1
	9 p.m. 11 p.m.	112.3	28.9	−22.2	119.0
	11 p.m. 1 a.m.	59.1	29.1	+18.0	106.2
	1 a.m. 3 a.m.	59.0	27.7	+ 7.9	94.6
	3 a.m. 5 a.m.	80.8	27.5	+21.5	129.8
	5 a.m. 7 a.m.	85.6	27.1	+ 16.9	129.6
	Total	1279.0	355.2	+28.7	1662.9
Feb. 1–2	7 a.m. to 9 a.m.	155.5	31.2	−32.5	154.2
	9 a.m. 11 a.m.	118.6	28.9	+ 6.8	154.3
	11 a.m. 1 p.m.	102.1	27.1	+ 1.9	131.1
	1 p.m. 3 p.m.	114.1	27.8	− 0.8	141.1
	3 p.m. 5 p.m.	93.4	24.8	− 1.7	116.5
	5 p.m. 7 p.m.	114.8	28.4	− 2.0	141.2
	7 p.m. 9 p.m.	120.9	29.5	− 6.4	144.0
	9 p.m. 11 p.m.	117.7	30.6	−18.3	130.0
	11 p.m. 1 a.m.	54.6	25.7	+ 19.2	99.5
	1 a.m. 3 a.m.	74.7	26.5	− 6.5	94.7
	3 a.m. 5 a.m.	75.0	25.5	+26.7	127.2
	5 a.m. 7 a.m.	71.4	27.5	+14.9	113.8
	Total	1212.8	333.5	+ 1.3	1547.6

TABLE 103.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 73.*

Date.	Energy derived from different sources. From body protein. (a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a−b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).	(g) Total heat production.	Energy from body material greater (+) or less (−) than output. (h) Amount (f−g).	(i) Proportion (h÷g).
1905.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Jan. 28–29	349	86	263	1017	567	1847	1866	− 19	−1.0
Jan. 29–30	406	98	308	1447	76	1831	1791	+ 40	+2.2
Jan. 30–31	391	96	295	1456	31	1782	1739	+ 43	+2.5
Jan. 31–Feb. 1	352	92	260	1327	91	1678	1663	+ 15	+0.9
Feb. 1–2	338	92	246	1413	[1]45	1614	1548	+ 66	+4.3
Total, 5 days	1836	464	1372	6660	720	8752	8607	+ 145	....
Av. per day	367	93	274	1332	144	1750	1721	+ 29	+1.7

[1] Glycogen gained.

TABLE 104.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 73.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f ÷ g).
Preliminary:								
1905.								
Jan. 28:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1 a.m. to 3 a.m..	[1]135.1	35.8	26.5	45.0	33.3	22.9	25.1	0.91
3 a.m. 5 a.m..	[1]133.6	37.0	27.6	56.2	42.1	28.6	25.9	1.11
5 a.m. 7 a.m..	[1]128.4	38.3	29.9	52.5	40.9	26.8	26.8	1.00
Total...........	[1]397.1	111.1	28.0	153.7	38.7	78.3	77.8	1.01
Jan. 28–29:								
7 a.m. to 9 a.m..	199.6	61.6	30.8	68.2	34.2	34.7	43.1	.81
9 a.m. 11 a.m..	184.1	50.4	27.4	62.7	34.1	31.9	35.3	.90
11 a.m. 1 p.m..	179.3	48.7	27.2	57.7	32.2	29.4	34.1	.86
1 p.m. 3 p.m..	154.5	43.7	28.3	52.6	34.1	26.8	30.6	.88
3 p.m. 5 p.m..	156.7	46.8	29.9	52.2	33.3	26.6	32.8	.81
5 p.m. 7 p.m..	183.4	50.8	27.7	55.7	30.3	28.3	35.6	.80
7 p.m. 9 p.m..	156.7	42.6	27.2	45.1	28.8	23.0	29.8	.77
9 p.m. 11 p.m..	142.0	48.0	33.8	50.2	35.3	25.5	33.6	.76
11 p.m. 1 a.m..	111.1	36.1	32.5	42.7	38.4	21.7	25.3	.86
1 a.m. 3 a.m..	115.7	40.1	34.7	37.5	32.5	19.1	28.1	.68
3 a.m. 5 a.m..	144.2	36.2	25.1	41.8	29.0	21.3	25.3	.84
5 a.m. 7 a.m..	138.4	39.2	28.3	42.5	30.7	21.7	27.4	.79
Total...........	1865.7	544.2	29.2	608.9	32.6	310.0	381.0	.81
Jan. 29–30:								
7 a.m. to 9 a.m..	182.9	63.7	34.8	62.6	34.2	31.8	44.6	.71
9 a.m. 11 a.m..	190.7	55.5	29.1	56.8	29.8	28.9	38.8	.75
11 a.m. 1 p.m..	162.6	47.6	29.3	48.8	30.0	24.8	33.3	.75
1 p.m. 3 p.m..	158.1	47.2	29.9	49.6	31.4	25.3	33.1	.76
3 p.m. 5 p.m..	149.2	51.8	34.6	47.4	31.7	24.1	36.3	.67
5 p.m. 7 p.m..	178.6	49.1	27.5	53.3	29.9	27.2	34.4	.79
7 p.m. 9 p.m..	151.2	45.6	30.2	46.1	30.5	23.5	31.9	.74
9 p.m. 11 p.m..	141.4	48.7	34.5	47.2	33.4	24.0	34.1	.71
11 p.m. 1 a.m..	101.1	28.4	28.1	36.8	36.4	18.7	19.9	.94
1 a.m. 3 a.m..	114.1	40.7	35.7	37.3	32.7	19.0	28.5	.67
3 a.m. 5 a.m..	136.8	37.4	27.3	37.3	27.3	19.0	26.1	.73
5 a.m. 7 a.m..	123.6	32.2	26.1	36.8	29.8	18.8	22.5	.83
Total...........	1790.8	547.9	30.6	560.0	31.3	285.1	383.5	.74
Jan. 30–31:								
7 a.m. to 9 a.m..	177.4	68.2	38.4	64.2	36.2	32.7	47.7	.68
9 a.m. 11 a.m..	174.3	49.5	28.4	52.2	30.0	26.6	34.7	.77
11 a.m. 1 p.m..	158.4	49.0	31.0	50.5	31.8	25.7	34.3	.75
1 p.m. 3 p.m..	161.3	50.1	31.0	50.7	31.5	25.8	35.0	.74
3 p.m. 5 p.m..	166.5	48.7	29.3	50.6	30.4	25.7	34.1	.76
5 p.m. 7 p.m..	169.5	46.2	27.3	49.9	29.4	25.4	32.3	.79
7 p.m. 9 p.m..	144.9	43.4	29.9	44.9	31.0	22.9	30.4	.75
9 p.m. 11 p.m..	143.5	37.3	26.0	40.9	28.5	20.8	26.1	.80
11 p.m. 1 a.m..	92.6	33.7	36.4	36.5	39.4	18.6	23.6	.79
1 a.m. 3 a.m..	106.8	33.0	30.9	33.2	31.1	16.9	23.1	.73
3 a.m. 5 a.m..	121.3	40.2	33.2	40.2	33.1	20.5	28.2	.73
5 a.m. 7 a.m..	122.6	33.7	27.5	27.9	22.8	14.2	23.6	.60
Total...........	1739.1	533.0	30.7	541.7	31.2	275.8	373.1	.74

[1] See p. 150.

TABLE 104.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
1906. Jan. 31–Feb. 1:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m. to 9 a.m.	158.4	55.1	34.8	56.0	35.4	28.5	38.6	.74
9 a.m. 11 a.m.	161.5	53.6	33.2	52.7	32.6	26.8	37.5	.72
11 a.m. 1 p.m.	168.1	49.5	29.4	50.2	29.9	25.6	34.6	.74
1 p.m. 3 p.m.	156.6	41.6	26.5	45.4	29.0	23.1	29.1	.80
3 p.m. 5 p.m.	140.8	43.3	30.7	43.1	30.6	21.9	30.3	.72
5 p.m. 7 p.m.	155.2	43.3	27.9	47.0	30.3	24.0	30.3	.79
7 p.m. 9 p.m.	143.1	42.9	30.0	46.2	32.3	23.5	30.1	.78
9 p.m. 11 p.m.	119.0	38.1	32.1	38.9	32.7	19.8	26.7	.74
11 p.m. 1 a.m.	106.2	30.3	28.5	34.6	32.6	17.6	21.2	.83
1 a.m. 3 a.m.	94.6	36.3	38.4	33.1	35.0	16.9	25.4	.66
3 a.m. 5 a.m.	129.8	32.7	25.2	32.7	25.2	16.6	22.9	.73
5 a.m. 7 a.m.	129.6	36.0	27.8	35.3	27.2	18.0	25.2	.71
Total	1662.9	502.7	30.2	515.2	31.0	262.3	351.9	.75
Feb. 1–2:								
7 a.m. to 9 a.m.	154.2	52.3	33.9	53.5	34.7	27.2	36.6	.74
9 a.m. 11 a.m.	154.3	44.6	28.9	43.0	27.9	21.9	31.2	.70
11 a.m. 1 p.m.	131.1	42.0	32.0	42.1	32.1	21.5	29.4	.73
1 p.m. 3 p.m.	141.1	41.3	29.3	42.9	30.4	21.8	28.9	.75
3 p.m. 5 p.m.	116.5	38.5	33.0	40.7	34.9	20.7	26.9	.77
5 p.m. 7 p.m.	141.2	46.8	33.2	43.6	30.9	22.2	32.8	.68
7 p.m. 9 p.m.	144.0	44.2	30.7	45.2	31.4	23.0	31.0	.74
9 p.m. 11 p.m.	130.0	41.6	32.0	39.8	30.6	20.3	29.1	.70
11 p.m. 1 a.m.	99.5	28.1	28.2	31.8	32.0	16.2	19.7	.82
1 a.m. 3 a.m.	94.7	33.7	35.6	30.0	31.7	15.3	23.6	.65
3 a.m. 5 a.m.	127.2	36.1	28.4	34.6	27.2	17.6	25.3	.70
5 a.m. 7 a.m.	113.8	36.3	31.9	34.8	30.5	17.7	25.4	.70
Total	1547.6	485.5	31.4	482.0	31.2	245.4	339.9	.72

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The relationships expressed by the oxygen thermal, carbon dioxide thermal, and respiratory quotients are given in table 104. It appears that on the first day the oxygen thermal quotient is the lowest, the carbon dioxide and respiratory quotient the highest, while on the succeeding days all three ratios are approximately constant. This statement does not take into account the fluctuations in these quotients during the 2-hour periods. In this experiment, however, the fluctuations seem less marked than in previous studies here reported.

METABOLISM EXPERIMENT NO. 74.

Immediately following the 5-day fast (experiment No. 73), an experiment was made with the same subject in order to obtain additional information regarding the effect on metabolism of the ingestion of food. The experiment began February 2, 1905, at 7 a. m., and continued without interruption for 72 hours. Thus, the series (experiments Nos. 73 and 74) represents a continuous 8-day experiment inside the respiration chamber, of which 5 days were without and 3 days with food. As previously pointed out the data obtained in the experiment with food, especially on the first and second days, indicate the transformations during transition from fasting to food.

Notes from diary, pulse records, and records of body movements.—Such notes from the diary as are deemed essential to an understanding of the condition of the subject during his stay in the calorimeter, the records of his pulse rate, and the usual records of body movements are given below:

Notes from diary.

Feb. 2, 1905:

7h30m a. m. Passed a fairly good night; awoke first time at 3h25m a. m., fell asleep again at 3h45m a. m. and awoke at 6h25m a. m. My tongue has a white coat and is swollen, showing my teeth marks on it; have a *sweet* taste in my mouth. Have just taken a little orange juice.

4 p. m. Feel very comfortable. The swelling of the tongue is gradually diminishing. I feel so good I could undertake another 5 days' fast to-morrow.

10 p. m. Have passed a very comfortable day, but it is becoming a little monotonous in here and I will be extremely glad to come out.

10h30m p. m. Pain in heart.

Feb. 3, 1905:

7h30m a. m. Have passed a fairly good night; was still sleepy when called.

8h15m a. m. Have just defecated, but with difficulty.

12 m. Finished my second allotment of milk. It is very rich and has a different taste from that I usually drink. Tongue still swollen and coated; taste in the mouth only moderately bad.

4 p. m. Feel very comfortable, but a little sleepy.

Feb. 4, 1905:

7h30m a. m. Did not sleep very well and was still very sleepy when I received the rising signal. My tongue is heavily coated with a brownish fur; taste in mouth is bad. I think the milk is making me bilious, as it is very heavy and rich.

8 a. m. My tongue is still swollen a little.

8h15m a. m. Defecated with much difficulty.

9 p. m. Have a slight dull (bilious) headache.

10 p. m. My headache is increasing and I have a nauseated feeling; did not take sufficient acids for the amount of milk I drank.

Pulse-rate—Experiment No. 74.[1]

Time.	7.30 a.m.	8 a.m.	10 a.m.	12 m.	2 p.m.	4 p.m.	6 p.m.	8 p.m.	10 p.m.
Feb. 2........	62	57	64	64	[2]75	[2]75	51	[2]64	59
Feb. 3........	55	56	55	54	53	57	62	54	54
Feb. 4........	65	66	66	63	[2]70	[2]66	[2]64	55	68

[1] Pulse taken while sitting. [2] Strong.

Movements of subject, duration 3 days, from Feb. 2, 7 a. m., to Feb. 5, 7 a. m., 1905.

February 2.

A. M.	
7^{h} 00^{m}	rise, urinate.
7 06 } 7 10 }	weigh self, etc.
7 15	food aperture.
7 18	sit.
7 20	Comb hair, food aperture.
7 30	drink, count pulse, write.
7 38	sit.
8 00	count pulse.
9 02	telephone, rise, food aperture.
9 04	sit.
9 07	rise, food aperture.
9 08	sit.
9 12	write.
9 36	telephone.
10 00	count pulse.
10 15	drink.
11 02	move about.
11 04	stand, read.
11 06	food aperture.
12 00	count pulse.
P. M.	
12^{h} 04^{m}	move about.
12 06	sit, write.
12 32	telephone.
1 02	rise, move about.
1 04	food aperture, lean on table, urinate.
1 08	move about.
1 10	food aperture.
1 26	sit, read.
2 00	count pulse.
2 04	move about, food aperture.
2 10	sit, write.
3 02	move about.
3 04	sit, write.
3 44	move about.
3 50	food aperture.
4 00	count pulse, write.
4 04	food aperture.
4 08	food aperture.
4 12	lean on table.
4 22	sit.
5 02	rise, lean on table.
5 08	telephone.
5 09	food aperture.
5 12	vigorous movement.
5 14	stand, doctor count pulse.
5 20	stand.
5 25	take temperature.
5 28	read.
P. M.	
6^{h} 00^{m}	count pulse.
6 04	food aperture.
6 08	sit, read.
7 00	rise, urinate.
7 04	move about.
7 16	food aperture.
7 24	sit.
7 42	lean on table, read.
7 48	sit.
8 00	count pulse.
8 02	rise, food aperture.
8 12	sit.
9 00	rise.
9 24	move.
9 38	sit.
10 00	count pulse.
10 02	open bed.
10 04	lie.
10 30	write.
11 00	rise.
11 02	close curtain, undress, urinate, retire.

February 3.

A. M.	
7^{h} 00^{m}	rise, urinate.
7 04 } 7 11 }	weigh self, etc.
7 17	food aperture.
7 18	sit.
7 30	count pulse.
8 00	count pulse.
8 02	move about.
8 10	lean on table.
8 15	defecate.
8 18	sit, read.
8 25	telephone, food aperture.
8 26	sit.
9 02	rise, food aperture.
9 08	rise, food aperture.
10 00	sit, count pulse.
10 20	rise, move about.
10 22	sit.
10 24	read.
11 02	move about, food aperture.
11 06	lean on table.
11 08	food aperture.
11 10	lean on table.
11 16	sit.
11 18	read.
11 26	rise, food aperture.
11 28	stand.
11 34	sit, read.
11 40	stand.
11 42	sit, read.
12 00	count pulse, write.
P. M.	
1^{h} 04^{m}	move about, urinate.
1 08	food aperture, lean on table, read.
1 16	move about, lean on table, read.
1 28	sit, read.
2 00	count pulse.
2 02	food aperture.
2 06	stand, eat.
2 16	stop eating.
2 18	sit, read.
2 20	food aperture.
3 46	asleep, head on table.
3 54	awake.
3 56	count pulse, write.
4 04	rise, food aperture.
4 08	move about.
4 12	sit, head on table, asleep.
4 14	rise, food aperture.
4 16	stand, read.
4 24	sit, asleep.
5 02	awake.
5 06	read.
5 38	telephone.
5 40	stand doctor read diary.
5 42	move about.
5 46	doctor count pulse.
5 54	food aperture.
5 56	take temperature.
6 00	count pulse.
6 04	rise, move about, sit.
6 05	food aperture.
6 10	read.
7 02	rise, urinate.
7 32	rise.
7 36	lean on table.
8 00	food aperture, count pulse.
8 06	stand, lean on table.
8 20	sit, read.
8 48	sit, head on table.
9 12	sit.
9 14	stand.
9 16	open bed.
9 20	lie.
10 00	count pulse.
10 16	lie.
11 00	rise, urinate.
11 02	close curtain, undress, retire.

Movements of subject.—Continued.

February 4.

Time	Movement
A. M.	
7h 00m	rise, urinate.
7 04 / 7 09	weigh self, etc.
7 16	food aperture, sit.
7 18	food aperture.
7 22	move about.
7 30	count pulse, write.
7 36	sit.
7 46	read.
8 00	count pulse.
8 08	move about.
8 10	food aperture.
8 15	defecate.
8 20	sit, read.
9 02	move about.
9 04	food aperture.
9 10	sit, read.
9 32	drink.
9 34	sit.
10 00	count pulse.
10 18	move about, lean on table.
10 26	sit.
10 32	read.
11 00	move about.
A. M.	
11h 06m	move about, food aperture.
11 36	sit.
11 50	food aperture.
12 00	count pulse.
P. M.	
12h 02m	sit, read.
1 02	urinate, move about, lean on table, read.
1 06	food aperture.
1 08	lean on table, read.
1 32	sit.
2 00	count pulse.
2 08	rise, food aperture.
2 10	sit.
2 40	move about.
3 12	rise, move about.
3 20	sit.
3 22	eat.
3 30	move about.
3 36	sit.
3 44	move about.
3 46	pick up papers.
3 48	walk about.
3 52	sit, read.
4 00	count pulse.
P. M.	
5h 02m	rise, move about.
5 08	lean on table, read.
5 38	walk about.
5 40	lean on table, read.
5 44	telephone.
5 52	move about.
6 00	count pulse, take temperature.
6 02	telephone.
6 04	food aperture.
6 12	rise, lean on table, read.
6 14	telephone.
6 30	sit, read.
7 00	rise, urinate.
7 06	lean on table, read.
7 20	walk.
7 24	sit.
8 00	food aperture, count pulse.
10 00	count pulse.
10 08	open bed.
10 12	lie.
11 00	rise, undress, urinate.
11 02	close curtain.

WATER AND OXYGEN CONSUMED AND URINE, CARBON DIOXIDE, AND WATER-VAPOR ELIMINATED.

The data showing the amounts of water consumed, the determinations in the urine per period and per day, the oxygen intake and output of carbon dioxide, and the elimination of water-vapor are shown in tables 105 to 109 inclusive. The methods of obtaining the data have previously been described.

TABLE 105.—*Record of water consumed*[1]—*Metabolism experiment No. 74.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	Total for day.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 2–3	272.1	148.8	91.1	45.6	45.7	603.3
Feb. 3–4	370.3	155.1	73.3	99.5	324.3	1022.5
Feb. 4–5	335.7	98.0	91.1	205.4	....	730.2

[1] Period during which water was consumed, was assumed in some instances. (See page 73.)

TABLE 106.—*Determinations in urine per period and per day—Metabolism experiment No. 74.*

Date and period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a+b).	(d) Reaction.	(e) Nitrogen.	(f) Phosphoric acid by titration (P_2O_5).	(g) Total creatinine.
1905.							
Feb. 2–3:	*Grams.*		*c. c.*		*Grams.*	*Grams.*	*Grams.*
7 a.m. to 1 p.m....	477.4	1.0070	474	Acid.....	3.30	0.461	0.265
1 p.m. 7 p.m....	619.7	1.0039	617	Acid.....	3.38	.392	.228
7 p.m. 11 p.m....	105.1	1.0150	104	Acid.....	1.49	.196	.175
11 p.m. 7 a.m....	316.7	1.0089	314	Acid.....	2.57	.341	.357
Total..............	1518.9	....	1509	....	10.74	1.390	1.020
Total by composite.	1518.9	1.0066	1509	Acid.....	10.76	1.381	1.060
Feb. 3–4:							
7 a.m. to 1 p.m. ...	724.1	1.0036	722	Neutral..	2.71	.315	.241
1 p.m. 7 p.m. ...	460.5	1.0044	458	Neutral..	2.39	.384	.247
7 p.m. 11 p.m. ...	215.1	1.0061	214	Acid.....	1.15	....	.148
11 p.m. 7 a.m. ...	494.7	1.0056	492	Neutral..	2.00	.299	.343
Total..............	1894.4	....	1886	....	8.25	....	.979
Total by composite.	1894.4	1.0043	1866	Neutral..	8.25	1.148	1.010
Feb. 4–5:							
7 a.m. to 1 p.m. ...	494.6	1.0034	493	Acid.....	1.79	.238	.220
1 p.m. 7 p.m. ...	484.6	1.0038	483	Acid.....	1.96	.308	.226
7 p.m. 11 p.m. ...	129.1	1.0107	127	Acid.....	0.96	....	.170
11 p.m. 7 a.m. ...	496.7	1.0056	494	Acid.....	2.07	.403	.224
Total..............	1605.0	....	1597	....	6.78	....	.840
Total by composite.	1605.0	1.0048	1597	Acid.....	6.77	1.141	.860
Total, 3 days.....	5018.3	....	4992	....	25.77	....	2.839

TABLE 107.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 74.*

	Feb. 2-3.	Feb. 3-4.	Feb. 4-5.	Total for 3 days.
(a) Weight....... ....grams..	1518.9	1894.4	1605.0	5018.3
(b) Water ....do....	1485.94	1866.17	1579.48	4931.59
(c) Solids, a—b ....do....	32.96	28.23	25.52	86.71
(d) Ash.........................do....	3.49	4.17	4.82	12.48
(e) Organic matter, c—d.......... do....	29.47	24.06	20.70	74.23
(f) Nitrogen......................do....	10.74	8.25	6.78	25.77
(g) Carbon .... do ...	7.29	6.06	5.46	18.81
(h) Hydrogen in organic matter....do....	1.97	1.52	1.28	4.77
(i) Oxygen (by difference) in organic matter, e—(f+g+h)...........grams..	9.47	8.23	7.18	24.88
(j) Phosphorus. ....do....	.578	.430	.498	1.506
Phosphoric acid (P_2O_5):				
(k) By fusion ....grams..	1.323	.986	1.141	3.450
(l) By titration ....do....	1.381	1.148	1.141	3.670
(m) Sulphur ....do....	.614	.511	.439	1.564
(n) Sulphur trioxide (SO_3)..... ....do....	1.533	1.278	1.097	3.908
(o) Total creatinine.............do....	1.06	1.01	.86	2.93
(p) Uric acid ....do....	.329	.537	.407	1.273
(q) Chlorine......................do....	.72	1.31	1.34	3.37
(r) Sodium chloride..............do....	1.19	2.17	2.21	5.57
(s) Heat of combustion .. ..calories..	88	68	61	217

TABLE 108.—*Record of water of respiration and perspiration—Metabolism experiment No. 74.*

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905.		
Preliminary:	*Grams.*	*Grams.*
Feb. 2: 5 a.m. to 7 a.m.	23.4	....
Feb. 2–3:		
7 a.m. to 9 a.m....	28.8	49.9
9 a.m. 11 a.m....	26.5	52.2
11 a.m. 1 p.m....	29.0	50.6
1 p.m. 3 p.m....	29.8	59.0
3 p.m. 5 p.m....	29.3	51.2
5 p.m. 7 p.m....	25.8	52.7
7 p.m. 9 p.m....	27.2	49.6
9 p.m. 11 p.m....	25.2	51.2
11 p.m. 1 a.m....	23.8	39.7
1 a.m. 3 a.m....	23.3	45.8
3 a.m. 5 a.m....	24.1	39.8
5 a.m. 7 a.m....	22.3	43.2
Total.............	....	584.9
Feb. 3–4:		
7 a.m. to 9 a.m....	28.0	40.5
9 a.m. 11 a.m....	25.7	48.4
11 a.m. 1 p.m....	25.5	42.3
1 p.m. 3 p.m....	26.6	49.8
3 p.m. 5 p.m....	26.7	45.4
5 p.m. 7 p.m....	27.1	49.9
7 p.m. to 9 p.m....	25.3	41.7
9 p.m. 11 p.m....	23.3	42.8
11 p.m. 1 a.m....	24.2	41.7
1 a.m. 3 a.m....	22.7	41.7
3 a.m. 5 a.m....	23.6	40.2
5 a.m. 7 a.m....	23.1	43.2
Total.............	....	527.6
Feb. 4–5:		
7 a.m. to 9 a.m....	23.4	48.7
9 a.m. 11 a.m....	25.8	45.3
11 a.m. 1 p.m....	26.3	42.2
1 p.m. 3 p.m....	25.7	44.9
3 p.m. 5 p.m....	27.4	44.7
5 p.m. 7 p.m....	27.3	49.4
7 p.m. 9 p.m....	26.8	44.1
9 p.m. 11 p.m....	24.5	43.2
11 p.m. 1 a.m....	26.3	40.8
1 a.m. 3 a.m....	24.2	41.6
3 a.m. 5 a.m....	25.4	40.6
5 a.m. 7 a.m....	22.6	39.4
Total.............	....	524.9

[1] Allowance has been made for water lost by absorbers, chair, bedding, and miscellaneous articles as follows: Feb. 2-3, 14.85 grams; Feb. 3-4, 12.49 grams; Feb. 4-5, 23.38 grams.

ELEMENTS AND MATERIALS KATABOLIZED IN BODY.

The usual methods were followed in obtaining the elements and materials katabolized in the body. The data are given in tables 110 and 111. As in the other food experiments reported in this publication the food and water consumption are treated separately from the katabolism. The importance of this conception of the relation of food to katabolism warrants its repetition.

TABLE 109.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 74.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Feb. 2........	Preliminary: 5 a. m. to 7 a. m..	20.9	....	924.4	....
Feb. 2–3......	7 a. m. to 9 a. m..	28.4	52.6	917.4	53.9
	9 a. m. 11 a. m..	30.2	49.8	919.8	51.0
	11 a. m. 1 p. m..	31.3	50.2	906.6	51.8
	1 p. m. 3 p. m..	35.2	55.0	901.2	55.8
	3 p. m. 5 p. m..	34.7	51.6	907.4	44.4
	5 p. m. 7 p. m..	31.1	45.6	920.8	44.4
	7 p. m. 9 p. m..	32.0	49.3	919.5	51.2
	9 p. m. 11 p. m..	29.1	42.4	924.1	41.2
	11 p. m. 1 a. m..	24.1	32.3	933.0	24.1
	1 a. m. 3 a. m..	23.9	33.0	934.8	33.0
	3 a. m. 5 a. m..	24.2	32.4	939.1	30.7
	5 a. m. 7 a. m..	24.9	34.4	944.9	30.7
	Total..........	....	528.6	.....	512.2
Feb. 3–4......	7 a. m. to 9 a. m..	35.7	65.1	936.0	55.2
	9 a. m. 11 a. m..	25.6	44.8	948.5	44.5
	11 a. m. 1 p. m..	32.9	49.0	937.5	43.1
	1 p. m. 3 p. m..	31.3	51.0	943.1	49.6
	3 p. m. 5 p. m..	36.4	48.9	944.3	48.1
	5 p. m. 7 p. m..	31.7	47.5	950.8	42.6
	7 p. m. 9 p. m..	25.0	41.7	964.1	37.6
	9 p. m. 11 p. m..	26.0	40.2	968.1	37.7
	11 p. m. 1 a. m..	21.4	36.9	968.9	32.2
	1 a. m. 3 a. m..	23.4	33.4	972.6	35.0
	3 a. m. 5 a. m..	22.0	36.4	975.7	29.3
	5 a. m. 7 a. m..	23.8	34.8	980.1	34.3
	Total...........	....	529.7	.....	489.2
Feb. 4–5......	7 a. m. to 9 a. m..	31.1	56.9	975.4	54.4
	9 a. m. 11 a. m..	32.0	44.5	975.6	40.7
	11 a. m. 1 p. m..	30.5	47.0	968.5	35.0
	1 p. m. 3 p. m..	36.5	49.3	961.9	52.3
	3 p. m. 5 p. m..	30.2	45.6	962.4	47.4
	5 p. m. 7 p. m..	36.3	51.7	963.5	44.4
	7 p. m. 9 p. m..	30.0	42.6	973.4	41.4
	9 p. m. 11 p. m..	34.1	44.0	971.5	43.6
	11 p. m. 1 a. m..	28.3	39.7	984.4	29.7
	1 a. m. 3 a. m..	27.2	32.7	986.3	37.6
	3 a. m. 5 a. m..	27.9	38.9	982.6	37.0
	5 a. m. 7 a. m..	28.9	34.3	985.3	31.4
	Total...........	....	527.2	.....	494.9

TABLE 110.—*Elements katabolized in body—Metabolism experiment No. 74.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Feb. 2, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	512.15	....	....	....	512.15	....
Outgo:						
Water in urine	1485.94	....	....	166.28	1319.66	....
Solids in urine	32.96	10.74	7.29	1.97	9.47	3.49
Water of respiration [1]	584.88	....	....	65.45	519.43	....
Carbon dioxide	528.55	....	144.14	....	384.41	....
Total	2632.33	10.74	151.43	233.70	2232.97	3.49
Loss	2120.18	10.74	151.43	233.70	1720.82	3.49
Second day, Feb. 3, 1905.						
Income: Oxygen from air	489.17	....	....	....	489.17	....
Outgo:						
Water in urine	1866.17	....	....	208.82	1657.35	....
Solids in urine	28.23	8.25	6.06	1.52	8.23	4.17
Water of respiration [1]	527.61	....	....	59.04	468.57	....
Carbon dioxide	529.74	....	144.46	....	385.28	....
Total	2951.75	8.25	150.52	269.38	2519.43	4.17
Loss	2462.58	8.25	150.52	269.38	2030.26	4.17
Third day, Feb. 4, 1905.						
Income: Oxygen from air	494.92	....	....	....	494.92	....
Outgo:						
Water in urine	1579.48	....	....	176.74	1402.74	....
Solids in urine	25.52	6.78	5.46	1.28	7.18	4.82
Water of respiration [1]	524.88	....	....	58.73	466.15	....
Carbon dioxide	527.19	....	143.79	....	383.40	....
Total	2657.07	6.78	149.25	236.75	2259.47	4.82
Loss	2162.15	6.78	149.25	236.75	1764.55	4.82

[1] Includes also water of perspiration.

TABLE 111.—*Elements and materials katabolized in body—Metabolism experiment No. 74.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 2–3	10.74	151.43	233.70	1720.82	1887.12	64.44	138.30	27.82	3.49
Feb. 3–4	8.25	150.52	269.38	2030.26	2209.31	49.50	112.48	87.88	4.17
Feb. 4–5	6.78	149.25	236.75	1764.55	1917.78	40.68	124.26	75.28	4.82
Total, 3 days.	25.77	451.20	739.83	5515.63	6014.21	154.62	375.04	190.98	12.48

OUTPUT OF HEAT.

The total heat production is recorded in the following table, together with the data from which it is derived.

TABLE 112.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 74.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Cals.*	*Cals.*	*Cals.*	*Cals.*
Feb. 2–3.....	7 a.m. to 9 a.m.........	139.2	30.2	+ 8.4	177.8
	9 a.m. 11 a.m.........	116.5	31.6	+ 5.6	153.7
	11 a.m. 1 p.m.........	114.1	30.7	+14.9	159.7
	1 p.m. 3 p.m.........	126.4	35.7	+20.1	182.2
	3 p.m. 5 p.m.........	137.3	31.0	−10.4	157.9
	5 p.m. 7 p.m.........	128.0	31.9	+ 0.6	160.5
	7 p.m. 9 p.m.........	123.2	30.1	− 4.4	148.9
	9 p.m. 11 p.m.........	116.8	31.1	− 7.9	140.0
	11 p.m. 1 a.m.........	66.3	24.3	− 2.0	88.6
	1 a.m. 3 a.m.........	78.6	27.9	+10.9	117.4
	3 a.m. 5 a.m.........	81.2	24.3	− 2.0	103.5
	5 a.m. 7 a.m.........	66.4	26.3	+ 8.5	101.2
	Total................	1294.1	355.0	+42.3	1691.4
Feb. 3–4.....	7 a.m. to 9 a.m.........	148.1	24.6	+13.5	186.2
	9 a.m. 11 a.m.........	100.5	29.2	− 0.5	129.2
	11 a.m. 1 p.m.........	109.7	25.7	+19.2	154.6
	1 p.m. 3 p.m.........	120.0	30.1	+22.5	172.6
	3 p.m. 5 p.m.........	112.3	27.5	− 0.3	139.5
	5 p.m. 7 p.m.........	116.3	30.2	+ 6.2	152.7
	7 p.m. 9 p.m.........	123.0	25.3	− 8.3	140.0
	9 p.m. 11 p.m.........	84.9	25.9	−10.2	100.6
	11 p.m. 1 a.m.........	71.3	25.3	+ 2.4	99.0
	1 a.m. 3 a.m.........	66.7	25.3	+ 8.1	100.1
	3 a.m. 5 a.m.........	81.2	24.4	− 0.3	105.3
	5 a.m. 7 a.m.........	71.2	26.2	+ 8.0	105.4
	Total................	1205.1	319.7	+60.4	1585.2
Feb. 4–5.....	7 a.m. to 9 a.m.........	153.3	30.0	+ 6.1	189.4
	9 a.m. 11 a.m.........	102.4	28.0	+ 3.1	133.5
	11 a.m. 1 p.m.........	115.2	26.2	+17.5	158.9
	1 p.m. 3 p.m.........	103.5	27.8	+31.3	162.6
	3 p.m. 5 p.m.........	101.7	27.6	− 0.8	128.5
	5 p.m. 7 p.m.........	128.3	30.4	− 1.0	157.7
	7 p.m. 9 p.m.........	115.8	27.3	− 5.0	138.1
	9 a.m. 11 p.m.........	115.6	26.7	−13.8	128.5
	11 p.m. 1 a.m.........	52.2	25.3	+11.8	89.3
	1 a.m. 3 a.m.........	69.8	25.7	+ 5.8	101.3
	3 a.m. 5 a.m.........	92.4	25.1	+ 1.0	118.5
	5 a.m. 7 a.m.........	73.6	24.5	+ 2.1	100.2
	Total................	1223.9	324.5	+58.1	1606.5

[1] See pp. 42-49.

BALANCE OF ENERGY.

In table 113, the energy derived from the oxidation of body protein, fat, and carbohydrates during the time of this experiment is shown. On the last 2 days the comparison with the heat production shows large discrepancies, approximating 4 per cent. No satisfactory explanation for such discrepancies has as yet appeared.

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The oxygen and carbon dioxide thermal quotients and the respiratory quotients obtained in this experiment are shown in table 114.

TABLE 113.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 74.*

Date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater (+) or less (—) than output.	
	From body protein.			(d) From body fat.	(e) From body glycogen.	(f) Total (d+e+f).		(h) Amount (f—g).	(i) Proportion (h÷g).
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).						
1905.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Feb. 2–3......	364	88	276	1319	116	1711	1691	+ 20	+1.2
Feb. 3–4......	280	68	212	1073	368	1653	1585	+ 68	+4.3
Feb. 4–5......	230	61	169	1185	315	1669	1607	+ 62	+3.9
Total, 3 days.	874	217	657	3577	799	5033	4883	+150	....
Av. per day..	291	72	219	1192	266	1678	1628	+ 50	+3.1

EFFECT OF INGESTION OF FOOD.

Diet.—While the diet of the subject was very simple, it contained in addition to the two articles used in experiment No. 72, a small quantity of apple and a few graham crackers. The same amount of each article of food was consumed each day. The use of modified milk was continued in this experiment.

Feces.—At 8.15 a. m., February 3, there were passed 61.4 grams of fresh feces, of which 23 grams were separated as belonging to food eaten before the fast began. The remainder, 38.4 grams, appeared more like "fasting feces" than the feces found in any other experiment following a period of fast but were not sufficiently colored with lampblack to warrant their acceptance as the result of fasting metabolism.[a] When partially dried these feces gave 10.1 grams of air-dry material. Subsequently two other portions, on February 4 and 5, were passed which obviously belonged to the food period, and were put together to form one sample, amounting to 67.9 grams. It was, however, considered

[a] For further discussion of fasting feces, see section on Feces, Part 3.

TABLE 114.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 74.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100 b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100 d÷a).	(f) Volume of carbon dioxide eliminated (d × 0.5091).	(g) Volume of oxygen consumed (b × 0.7).	(h) Respiratory quotient (f÷g).
1905. Feb. 2–3:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m. to 9 a.m.	177.3	53.9	30.3	52.6	29.6	26.8	37.7	.71
9 a.m. 11 a.m.	153.7	51.0	33.2	49.8	32.4	25.4	35.7	.71
11 a.m. 1 p.m.	159.7	51.8	32.4	50.2	31.5	25.6	36.2	.71
1 p.m. 3 p.m.	182.2	55.8	30.6	55.0	30.2	28.0	39.1	.72
3 p.m. 5 p.m.	157.9	44.4	28.1	51.6	32.7	26.3	31.1	.85
5 p.m. 7 p.m.	160.5	44.4	27.7	45.6	28.4	23.2	31.1	.75
7 p.m. 9 p.m.	148.9	51.2	34.4	49.3	33.1	25.1	35.8	.70
9 p.m. 11 p.m.	140.0	41.2	29.4	42.4	30.2	21.5	28.9	.75
11 p.m. 1 a.m.	88.6	24.1	27.2	32.3	36.4	16.4	16.8	.98
1 a.m. 3 a.m.	117.4	33.0	28.1	33.0	28.1	16.8	23.1	.73
3 a.m. 5 a.m.	103.5	30.7	29.6	32.4	31.3	16.5	21.5	.77
5 a.m. 7 a.m.	101.2	30.7	30.3	34.4	34.0	17.5	21.5	.82
Total.........	1691.4	512.2	30.3	528.6	31.3	269.1	358.5	.75
Feb. 3–4:								
7 a.m. to 9 a.m.	186.2	55.2	29.7	65.1	35.0	33.1	38.6	.86
9 a.m. 11 a.m.	129.2	44.5	34.4	44.8	34.6	22.8	31.1	.73
11 a.m. 1 p.m.	154.6	43.1	27.9	49.0	31.7	24.9	30.2	.83
1 p.m. 3 p.m.	172.6	49.6	28.7	51.0	29.6	26.0	34.7	.75
3 p.m. 5 p.m.	139.5	48.1	34.5	48.9	35.0	24.9	33.7	.74
5 p.m. 7 p.m.	152.7	42.6	27.9	47.5	31.1	24.2	29.9	.81
7 p.m. 9 p.m.	140.0	37.6	26.8	41.7	29.8	21.3	26.3	.81
9 p.m. 11 p.m.	100.6	37.7	37.5	40.2	40.0	20.5	26.4	.78
11 p.m. 1 a.m.	99.0	32.2	32.5	36.9	37.3	18.8	22.5	.84
1 a.m. 3 a.m.	100.1	35.0	35.0	33.4	33.4	17.0	24.5	.69
3 a.m. 5 a.m.	105.3	29.3	27.8	36.4	34.5	18.5	20.5	.90
5 a.m. 7 a.m.	105.4	34.3	32.5	34.8	33.0	17.7	24.0	.74
Total.........	1585.2	489.2	30.9	529.7	33.4	269.7	342.4	.79
Feb. 4–5:								
7 a.m. to 9 a.m.	189.4	54.4	28.7	56.9	30.0	29.0	38.1	.76
9 a.m. 11 a.m.	133.6	40.7	30.5	44.5	33.3	22.6	28.5	.79
11 a.m. 1 p.m.	158.9	35.0	22.1	47.0	29.6	24.0	24.5	.98
1 p.m. 3 p.m.	162.6	52.3	32.1	49.3	30.3	25.1	36.6	.69
3 p.m. 5 p.m.	128.5	47.4	36.9	45.6	35.5	23.2	33.2	.70
5 p.m. 7 p.m.	157.6	44.4	28.2	51.7	32.8	26.3	31.1	.85
7 p.m. 9 p.m.	138.1	41.4	30.0	42.6	30.8	21.7	28.9	.75
9 p.m. 11 p.m.	128.5	43.6	33.9	44.0	34.2	22.4	30.5	.74
11 p.m. 1 a.m.	89.3	29.7	33.3	39.7	44.4	20.2	20.8	.97
1 a.m. 3 a.m.	101.3	37.6	37.2	32.7	32.3	16.7	26.3	.63
3 a.m. 5 a.m.	118.5	37.0	31.2	38.9	32.8	19.8	25.9	.77
5 a.m. 7 a.m.	100.2	31.4	31.3	34.3	34.2	17.4	22.0	.79
Total.........	1606.5	494.9	30.8	527.2	32.8	268.4	346.4	.78

advisable to make complete analyses of both samples of feces in so far as practicable, and the more essential determinations were fortunately secured on both samples. It was impossible to determine fat in feces owing to the small amount of material. After it had been discovered that the method ordinarily

TABLE 115.—*Percentage composition of food and feces—Metabolism experiment No. 74.*

Laboratory number.	Kind of material.	(a) Water.	(b) Protein.	(c) Fat.	(d) Carbohydrates.	(e) Ash.	(f) Nitrogen.	(g) Carbon.	(h) Hydrogen.	(i) Heat of combustion per gram.
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Cals.
3826	Milk	79.47	2.98	12.03	4.86	0.66	0.48	12.28	1.92	1.478
3827	Apple	86.11	.15	....	13.53	.22	.03	5.70	.90	.540
3828	Orange juice	87.87	.49	....	11.27	.37	.08	4.64	.76	.439
3829	Graham crackers	5.10	5.18	10.32	77.77	1.63	.91	44.46	7.08	4.462
3838	Feces	75.08	9.06	[1]3.82	3.52	3.52	1.45	13.32	1.91	1.533
3839	Feces	67.51	6.54	[1]6.56	12.62	6.77	1.04	17.02	2.57	2.016

[1] Assumed. See Analyses of Feces, Part 3, of this report.

TABLE 116.—*Weight, composition, and heat of combustion of food and feces—Metabolism experiment No. 74 (quantities of food per day).*

	Food.					Feces.			
	[1]3826. Milk.	[1]3827. Apple.	[1]3828. Orange juice.	[1]3829. Graham crackers.	Total for day.	[1]3838.	[1]3839.	Total for 3 days.	Average per day.
(a) Weight.......grams..	1201.00	122.70	312.90	35.00	1670.60	38.40	67.90	106.30	35.43
(b) Water..........do....	953.64	105.66	274.95	1.79	1336.04	28.83	45.84	74.67	24.89
(c) Protein.........do....	35.76	.18	1.53	1.81	39.28	3.48	4.44	7.92	2.64
(d) Fat............do....	144.36	....	....	3.61	147.97	3.39	4.45	7.84	2.61
(e) Carbohydrates..do....	58.32	16.59	35.26	27.22	137.39	1.35	8.57	9.92	3.31
(f) Ash............do....	7.92	.27	1.16	.57	9.92	1.35	4.60	5.95	1.98
(g) Nitrogen.......do....	5.76	.04	.25	.32	6.37	.56	.71	1.27	.42
(h) Carbon.........do....	147.36	6.99	14.52	15.56	184.43	5.11	11.56	16.67	5.56
(i) Hydrogen......do....	23.04	1.10	2.38	2.48	29.00	.73	1.75	2.48	.83
(j) Oxygen (by difference) grams..............	62.28	8.64	19.64	14.28	104.84	1.82	3.44	5.26	1.75
(k) Heat of combustion calories.............	1774	66	137	156	2133	59	137	196	65

[1] Laboratory number.

used for determining the fat in feces gives results that are too low (see below), it was found that unfortunately the samples for this experiment had been used up in making other analyses. The amount of fat in the feces was therefore estimated by the method explained under Analyses of Feces.

Percentage composition of food and feces.—The percentage composition and heat of combustion per gram of food and feces are given in table 115. The amounts of food and feces and the elements and nutritive ingredients, of which they consisted, together with the heat of combustion, are shown in table 116.

Elements and materials absorbed from food.—From the analyses of the food and feces, the amounts of nitrogen, carbon, hydrogen, oxygen, and ash of the absorbed food were obtained. Since the food was identical on all 3 days, and since the total amount of feces belonging to the experiment was apportioned equally among the different days of the experiment, the only variations in the quantities of elements absorbed on the different days were such as occurred

TABLE 117.—*Elements absorbed from food—Metabolism experiment No. 74.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Feb. 2, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Food and drink:						
Solids in food..........	334.56	6.37	184.43	29.00	104.84	9.92
Water in food..........	1336.04	....	....	149.50	1186.54	....
Water in drink..........	603.30	....	....	67.51	535.79	....
Total..............	2273.90	6.37	184.43	246.01	1827.17	9.92
Feces:						
Solids..................	10.54	.42	5.56	.83	1.75	1.98
Water..................	24.89	....	....	2.79	22.10	....
Total..............	35.43	.42	5.56	3.62	23.85	1.98
Absorbed [1]..........	2238.47	5.95	178.87	242.39	1803.32	7.94

[1] For February 3, the amounts of hydrogen and oxygen absorbed are 289.80 and 2175.61 grams respectively; for February 4, the corresponding amounts are 256.50 and 1916.02 grams.

as a result of different amounts of water drunk. The elements absorbed on February 2 are shown in table 117, and to avoid repetition, the amounts of hydrogen and oxygen absorbed on the second and third days of the experiment are given in a note following the table.

As has been explained in considering previous experiments, the quantities of absorbed material are computed in terms of body protein, body fat, and glycogen, by means of the formulæ given on page 38. The results show that on the first day there were absorbed 35.70 grams of protein, 133.80 grams of fat, and 131.52 grams of carbohydrate. Although there were fluctuations in the quantity of water consumed on the two subsequent days, the quantities of nitrogen, carbon, hydrogen of organic matter, and oxygen of organic matter were constant on all days, and the same amounts of materials were absorbed from the food daily. In carrying out the calculations by means of the formulæ, however, slight differences are obtained in the amounts of fat and carbohy-

drates for each of the 3 days, but the differences are mostly in the second decimal place. These variations may be noted in lines *d* and *g* of table 121 beyond.

Amounts of ingredients of food absorbed and corresponding amounts of body materials.—A comparison of the amounts of food protein, fat, and carbohydrates determined by proximate analyses with the computed amounts of body protein, fat, and carbohydrates derived from the elementary analyses is shown in table 118. It has previously been stated that the quantities of food were the same each day. Since the feces for the experiment were divided equally among the 3 days, the data for all 3 days are identical.

Energy of material absorbed from food.—The nutrients of the absorbed food expressed in terms of body materials, yielded for each day the following

TABLE 118.—*Amounts of ingredients of food absorbed and body materials derived from them—Metabolism experiment No. 74 (quantities per day).*

	(a) Food.	(b) Feces.	(c) Absorbed (a—b).	(d) Body material.[1]
Protein............grams..	39.28	2.64	36.64	35.70
Fat............do....	147.97	2.61	145.36	133.85
Carbohydrates............do....	137.39	3.31	134.08	131.48
Ash............do....	9.92	1.98	7.94	7.94
Energy............calories..	2133	65	2068	2030

[1] The amounts of water absorbed as calculated by the formulæ were as follows: Feb. 2, 1980.06 grams; Feb. 3, 2349.24 grams, and Feb. 4, 2056.95 grams.

amounts of energy: From protein, 202 calories; from fat, 1277 calories; and from carbohydrates, 551 calories, a total of 2030 calories.

Changes in body-weight compared with balance of income and outgo.—The comparison made in table 119 has been previously explained for similar tables. When the multiplicity of weighings is taken into consideration, the balance obtained in this experiment is extremely satisfactory.

BALANCE OF INTAKE AND OUTPUT.

In order to determine to what extent the food supplied the necessary material for the metabolic activity during this experiment, the balance tables 120 and 121 were prepared. There was an increasing gain of water throughout the experiment. The daily loss of protein decreased rapidly as the experiment progressed. The body was nearly in equilibrium as regards fat, while there was a marked storage of carbohydrates and ash on all days. The diet furnished an average excess of 368 calories of energy.

TABLE 119.—*Comparison of changes in body weight with balance of income and outgo—Metabolism experiment No. 74.*

	Feb. 2-3.	Feb. 3-4.	Feb. 4-5.	Total for 3 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Food	1670.60	1670.60	1670.60	5011.80	1670.60
(*b*) Water consumed	603.30	1022.50	730.20	2356.00	785.33
(*c*) Oxygen	512.15	489.17	494.92	1496.24	498.75
(*d*) Total ($a+b+c$)	2786.05	3182.27	2895.72	8864.04	2954.68
Outgo:					
(*e*) Urine[1]	1433.10	1716.40	1603.00	4752.50	1584.17
(*f*) Feces	....	61.40	30.00	91.40	30.47
(*g*) Carbon dioxide	528.55	529.74	527.19	1585.48	528.49
(*h*) Water of respiration and perspiration	584.88	527.61	524.88	1637.37	545.79
(*i*) Total ($e+f+g+h$)	2546.53	2835.15	2685.07	8066.75	2688.92
(*j*) Gain of body material ($d-i$)	239.52	347.12	210.65	797.29	265.76
(*k*) Gain of body weight	231.00	342.00	200.00	773.00	257.67

[1] The data in this line should not be confounded with urine data in other tables. See explanation, p. 66.

TABLE 120.—*Distribution of intake and outgo of water—Metabolism experiment No. 74.*

Date.	Outgo from the body. (*a*) Water of urine and feces.[1]	(*b*) Water of respiration and perspiration.	(*c*) Total ($a+b$).	Balance of preformed water. (*d*) Preformed (katabolized) water in outgo.[2]	(*e*) Intake in food and drink.	(*f*) Gain of preformed water ($d-e$).	(*g*) Water of oxidation of organic hydrogen ($c-d$).
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 2-3	1485.9	584.9	2070.8	1887.1	1939.3	52.2	183.7
Feb. 3-5	1909.3	527.6	2436.9	2252.4	2358.5	106.1	184.5
Feb. 5-6	1600.6	524.9	2125.5	1938.9	2066.3	127.4	186.6
Total, 3 days	4995.8	1637.4	6633.2	6078.4	6364.1	285.7	554.8
Av. per day	1665.3	545.8	2211.1	2026.1	2121.4	95.3	184.9

[1] Water in feces passed on the second and third days assumed as 43.13 and 21.07 grams respectively. In obtaining these amounts it is assumed that water existed in the feces for these two days in the same proportion that it did in the total feces of the experiment.
[2] Figures for second and third days include assumed water in feces.

TABLE 121.—*Balance of intake and output of nutrients, ash, and energy—Metabolism experiment No. 74.*

	Feb. 2-3.	Feb. 3-4.	Feb. 4-5.	Total for 3 days.	Average per day.
Body protein:					
(*a*) Computed from elements absorbed from food....gms..	35.70	35.70	35.70	107.10	35.70
(*b*) Katabolized..............do...	64.44	49.50	40.68	154.62	51.54
(*c*) Loss to body ($a-b$).......do...	28.74	13.80	4.98	47.52	15.84
Body fat:					
(*d*) Computed from elements absorbed from food......gms..	133.80	133.93	133.83	401.56	133.85
(*e*) Katabolized..............do...	138.30	112.48	124.26	375.04	125.01
(*f*) Gain (+) or loss (—) to body ($d-e$)................gms..	—4.50	+21.45	+9.57	+26.52	+8.84
Body carbohydrates:					
(*g*) Computed from elements absorbed from food......gms..	131.52	131.41	131.50	394.43	131.48
(*h*) Katabolized..............do...	27.82	87.88	75.23	190.93	63.64
(*i*) Gain to body ($g-h$).......do...	103.70	43.53	56.27	203.50	67.83
Ash:					
(*j*) In food absorbed.........gms..	7.94	7.94	7.94	23.82	7.94
(*k*) Eliminated in urine......do...	3.49	4.17	4.82	12.48	4.16
(*l*) Gain to body ($j-k$).......do...	4.45	3.77	3.12	11.34	3.78
Energy:					
(*m*) Of food absorbed (determined) calories....................	2068	2068	2068	6204	2068
(*n*) Heat production plus potential energy of urine........cals..	1779	1653	1668	5100	1700
(*o*) Gain to body ($m-n$).......do..	289	415	400	1104	368

METABOLISM EXPERIMENT NO. 75.

Immediately following the 5-day fast, experiment No. 73, the subject had remained in the respiration chamber for 3 days with food. From the morning of February 5, until the evening of March 3, he had been engaged in light occupation, assisting about the laboratory. During this preliminary period his diet had consisted in large part of vegetable materials, milk, and eggs.

On the evening of March 3, 1905, he entered the respiration chamber and went to bed at 11 p. m. At 1 a. m., March 4, the preliminary analyses of the respiratory products were begun. The experiment proper commenced at 7 a. m., March 4, and continued 7 days, during which time no food was eaten. The general routine was similar to that followed in previous experiments with this subject.

This experiment was the most successful of the series conducted with S. A. B. Though he made a large number of notes concerning various symptoms of illness, nevertheless his verdict at the end of each day (except the sixth), was that he had "passed a comfortable day."

Notes from diary, pulse records, and records of body movements.—The notes from the diary of the subject which embrace practically all his observations concerning his physical and mental condition, are shown below, together with the pulse records and the record of body movements.

Notes from diary.

March 4, 1905:

7^h15^m a. m. Passed a fairly good night, though I awoke a few times.

9^h10^m a. m. Defecated.

9^h15^m a. m. Commenced wearing rectal thermometer.

2^h30^m p. m. Feel sleepy.

3^h40^m p. m. Awoke from a nap lasting about 1 hour.

4 p. m. Am commencing to have a sour taste in the mouth; tongue coated thinly with a white fur.

10 p. m. Have a slight headache; eyes feel tired and I am very sleepy. Passed a very comfortable day except for slight pain in the heart.

March 5, 1905.

7^h15^m a. m. Slept fairly well but did not feel like rising. Am nervous and very weak.

7^h30^m a. m. Have an acrid taste in my mouth; tongue is coated with a whitish fur, and is swollen.

8^h10^m a. m. Had an inclination to defecate.

8^h20^m a. m. Feel very weak.

9^h10^m a. m. Made another ineffectual attempt to defecate.

10 p. m. Passed a comfortable day.

March 6, 1905:

7^h15^m a. m. Slept fairly well, though not continuously. Feel weak and extremely nervous. Tongue is swollen and coated with a white fur; sweetish taste in mouth. Eyes are clear and bright.

8^h10^m a. m. Attempted to defecate, but could not. Colon is filled with feces and if they could be removed I would feel considerably better.

9^h50^m a. m. Made another ineffectual attempt to defecate.

10 p. m. Have passed a very comfortable day. The weakness I felt in the morning passed away later.

March 7, 1905:

7^h20^m a. m. Slept very well. My tongue is swollen and coated with a brownish-white fur; sweet taste in mouth. Eyes are clear and bright. Feel a little weak.

7^h30^m a. m. Rectal thermometer is commencing to irritate me.

9^h40^m a. m. Took off rectal thermometer.

12^h10^m p. m. Made an unsuccessful attempt to defecate.

2^h22^m p. m. Commenced to wear rectal thermometer. It does not feel comfortable.

5^h55^m p.m. Took off rectal thermometer. Tried the soap suppository, but it caused considerable pain and I was compelled to remove it. Soreness in rectum.

10 p. m. Passed a comfortable day. Feel a little weaker.

March 8, 1905:

7^h30^m a. m. Slept continuously until 5^h50^m a. m. Feel a little weak and despondent. Tongue swollen and thickly coated; sweet taste in mouth. Eyes are bright and clear; face does not show any signs of fasting.

10 p. m. Passed a very comfortable day. At times I felt sleepy and managed to get a few naps.

March 9, 1905:

7^h20^m a. m. Slept very well. My tongue is swollen and coated with a thick white fur. Eyes are clear and bright. Feel a little weak as usual, but my nerves are stronger.

8^h10^m a. m. Made an unsuccessful attempt to defecate.

3^h40^m p. m. A slight bilious headache is commencing to come on; my eyes are painful and blurred.

5^h20^m p. m. Tongue and gums sore.

9^h10^m p. m. Made another unsuccessful attempt to defecate.

9^h18^m p. m. Commenced to wear rectal thermometer. Feels all right.

10 p. m. Felt very badly all day, but improved in the evening, and feel considerably stronger now.

March 10, 1905:

7^h20^m a. m. Did not sleep continuously for one-half hour. The sore gums and swollen tongue made that an impossibility; tongue is coated with a white fur.

1^h25^m p. m. Took off rectal thermometer.

10 p. m. Have passed a very good day, except for swollen tongue. Feel considerably stronger than at any other time. Could do some hard work.

Pulse-rate—Experiment No. 75.[1]

Time.	Pulse rate.	Time.	Pulse rate.	Time.	Pulse rate.
Mar. 4, 7^h30^m a.m..	68	Mar. 6, 12^h00^m a.m..	56	Mar. 8, 6^h00^m p.m..	54
8 00 a.m..	66	2 00 p.m..	58	8 00 p.m..	51
10 00 a.m..	59	4 00 p.m..	58	10 00 p.m..	48
12 00 a.m..	55	6 00 p.m..	66	Mar. 9, 7 30 a.m..	54
2 00 p.m..	[2]57	8 00 p.m..	58	8 00 a.m..	54
4 00 p.m..	[3]52	10 00 p.m..	49	10 00 a.m..	[8]54
6 00 p.m..	53	Mar. 7, 7 30 a.m..	59	12 00 a.m..	[3]52
8 00 p.m..	52	8 00 a.m..	61	2 00 p.m..	48
10 00 p.m..	51	10 00 a.m..	52	6 00 p.m..	44
Mar. 5, 7 30 a.m..	[4]82	12 00 a.m..	58	8 00 p.m..	45
8 00 a.m..	68	2 00 p.m..	55	10 00 p.m..	47
10 00 a.m..	62	4 00 p.m..	54	Mar. 10, 7 30 a.m..	57
12 00 a.m..	64	6 07 p.m..	52	8 00 a.m..	55
2 00 p.m..	61	8 00 p.m..	53	10 00 a.m..	54
4 00 p.m..	67	10 00 p.m..	49	12 00 a.m..	51
6 00 p.m..	[4]61	Mar. 8, 7 35 a.m..	74	2 10 p.m..	50
8 00 p.m..	54	8 00 a.m.	[7]58	4 00 p.m..	52
10 00 p.m..	[3]53	10 00 a.m..	58	6 00 p.m..	50
Mar. 6, 7 30 a.m..	70	12 00 a.m..	53	8 05 p.m..	[9]44
8 00 a.m..	[5]63	2 00 p.m..	56	10 00 p.m..	48
10 00 a.m..	[6]55	4 00 p.m..	54		

[1] Pulse taken while sitting.
[2] Very irregular.
[3] Very faint.
[4] Irregular.
[5] Faint and irregular.
[6] Regular.
[7] Strong and regular.
[8] Regular but faint.
[9] Very faint but regular.

Movements of subject, duration 7 days, from Mar. 4, 7 a. m., to Mar. 11, 7 a. m., 1905.

March 4.

A. M.	
$7^h\ 00^m$ – 7 08	sit, rise, open curtain, urinate, weigh self, etc.
7 16	food aperture.
7 22	dress, raise table.
7 24	comb hair, telephone.
7 25	rise, food aperture, drink.
7 26	sit.
7 30	count pulse.
7 44	telephone.
7 46	move about, sit.
7 50	drink.
7 53	food aperture, sit.
8 00	count pulse.
8 06	telephone.
8 08	read.
8 15	drink.
9 00	drink.
9 02	rise, move about.
9 04	food aperture.
9 08	close curtain.
9 10	defecate.
9 15	adjust thermometer.
9 20	open curtain, sit.
9 30	read.
9 40	drink.
9 43	rise, food aperture, sit.
9 53	rise, food aperture.
10 00	count pulse.
10 15	drink.
10 22	telephone, read.
10 50	drink.
11 04	rise, move about, urinate.
11 06	sit.
11 34	write.
11 35	drink.
11 42	read.
12 00	count pulse.
P. M.	
$12^h\ 30^m$	drink.
1 02	telephone, rise, food aperture.
1 30	drink, read.
1 44	rise, food aperture.
2 00	count pulse.
2 02	rise, stretch self, sit.
2 04	read.
2 24	head on table, asleep.
3 14	awake, stretch self.
3 16	asleep.
3 44	awake.
P. M.	
$3^h\ 48^m$	rise, food aperture, sit.
3 50	drink.
3 56	write.
4 00	count pulse.
4 10	read.
4 28	rise, food aperture, sit.
4 32	read.
5 00	drink.
5 01	rise, food aperture, sit.
5 04	read.
5 10	move about.
5 20	stand, doctor count pulse.
5 22	sit, read.
6 00	count pulse, drink.
6 36	change position.
6 40	drink.
7 02	move about.
7 04	urinate, telephone.
7 06	move about, food aperture, sit.
7 22	telephone.
7 35	drink.
7 42	rise, food aperture, sit.
8 00	count pulse.
8 18	change position.
8 36	drink.
9 34	rise, stand.
9 36	rise, telephone.
9 58	sit, telephone.
10 00	count pulse.
10 10	rise, move about.
10 12	telephone, sit.
10 14	move about, food aperture.
10 16	open bed, make motions, write.
10 20	sit.
11 02	rise, urinate, undress.

March 5.

A. M.	
$7^h\ 02^m$	open curtain, rise.
7 04	urinate, fold bed, telephone.
7 05 – 7 09	weigh self, etc.
7 12	food aperture.
7 16	dress.
7 20	raise table, sit, telephone.
7 25	drink.
7 26	comb hair, telephone.
7 28	stand, telephone.
$7^h\ 30^m$	count pulse.
7 50	drink.
8 00	count pulse.
8 02	remove thermometer.
8 04	food aperture.
8 06	food aperture.
8 10	close curtain, attempt to defecate.
8 18	open curtain, sit.
8 20	drink.
8 38	head on table.
9 02	food aperture.
9 04	move about, drink.
9 06	food aperture.
9 10	close curtain, attempt to defecate.
9 12	open curtain.
9 16	sit.
9 20	adjust thermometer.
9 26	asleep.
9 32	awake.
9 43	drink.
9 44	asleep.
9 48	awake.
10 00	count pulse.
10 12	rise, food aperture, sit.
10 14	read.
11 35	drink.
11 50	move about.
12 00	count pulse.
P. M.	
$12^h\ 10^m$	rise, food aperture, sit.
12 12	read.
12 30	drink.
1 02	rise, food aperture, urinate, sit, read.
1 25	drink.
2 00	count pulse.
2 28	stop reading.
2 56	asleep.
4 04	awake, count pulse, asleep.
4 08	awake, rise, food aperture.
4 10	move about, drink, sit.
4 24	rise, food aperture.
4 26	sit, read.
5 16	rise.
5 20	drink.
5 22	stand, doctor count pulse.
5 26	sit, read.
6 00	count pulse.
6 45	drink.
6 54	telephone.

***Movements of subject*.—Continued.**

***March 5* (cont.)**

Time	Movement
P. M.	
$6^h\ 58^m$	rise, stand, sit.
7 04	rise, food aperture, urinate, stand.
7 06	move about, sit.
7 45	drink.
8 00	count pulse.
8 10	telephone.
8 26	rise, lean on table.
8 28	move about, sit.
8 50	rise, lean on table, sit.
9 00	drink.
9 06	rise, food aperture, telephone.
9 45	drink.
10 00	count pulse.
10 08	rise, lower table, open bed, sit.
10 18	telephone.
10 46	lie.
11 04	rise, urinate, undress, close curtain.

March 6.

Time	Movement
A. M.	
$7^h\ 00^m$	rise, open curtain.
7 02	urinate, fold bed, weigh self, etc.
7 14	dress, adjust table.
7 16	food aperture, sit, comb hair.
7 25	drink.
7 30	count pulse.
7 36	read.
8 00	count pulse.
8 05	drink.
8 08	move about, food aperture.
8 12	remove thermometer.
8 14	attempt to defecate.
8 18	sit.
8 45	drink.
9 02	rise, food aperture, move about.
9 14	move about.
9 16	stand, blood sample taken.
9 20	move about.
9 26	stand.
9 34	sit.
9 36	rise, food aperture.
9 50	attempt to defecate, drink.
9 52	move about.
9 56	adjust thermometer.
10 00	count pulse.
A. M.	
$10^h\ 02^m$	write.
10 34	move about.
10 35	drink.
10 38	sit.
10 46	read.
11 00	move about.
11 07	food aperture.
11 08	work at food aperture.
11 26	sit.
11 48	food aperture, move about.
11 50	drink.
12 00	count pulse.
P. M.	
$12^h\ 02^m$	open bed, lie.
12 10	food aperture, lie, asleep.
1 02	awake, move, rise, food aperture.
1 08	urinate, fold bed.
1 14	food aperture, telephone.
1 16	raise table, arrange books, sit, drink.
1 55	drink.
2 00	count pulse.
2 02	read.
3 00	drink.
3 02	move about, blood sample taken, stand.
3 10	sampling finished.
3 12	food aperture.
3 14	sit.
4 00	count pulse.
4 05	drink.
4 50	drink.
5 02	rise, food aperture.
5 10	stand.
5 26	food aperture.
5 28	stand, doctor count pulse.
5 34	food aperture.
5 36	read.
6 00	count pulse.
6 05	drink.
6 32	rise, lean on table.
7 00	drink.
7 02	rise, food aperture.
7 04	urinate, sit, read.
7 06	telephone.
7 26	rise, food aperture.
7 35	rise, food aperture.
7 55	drink.
8 00	count pulse.
8 18	rise, move about, sit.
8 20	rise, telephone.
P. M.	
$8^h\ 24^m$	telephone.
8 26	rise, sit (3 times).
9 00	drink.
9 05	food aperture.
9 34	rise, urinate, walk about, sit.
9 55	drink.
10 00	count pulse.
10 02	rise, food aperture, stand.
10 04	lower table, open bed.
10 08	move about, move papers.
10 10	recline.
10 30	telephone.
11 02	rise, urinate.
11 04	undress.
11 06	close curtain.

March 7.

Time	Movement
A. M.	
$7^h\ 00^m$	rise, open curtain.
7 04 } 7 08 }	urinate, weigh self, etc.
7 11	food aperture.
7 14	dress, raise table, sit.
7 16	comb hair.
7 25	drink.
7 30	count pulse.
7 34	telephone.
7 36	rise, food aperture, sit.
8 10	drink.
9 00	drink.
9 04	move about.
9 06	sit, blood sample taken.
9 14	food aperture.
9 16	move about.
9 20	sit, read.
9 40	remove thermometer.
9 42	food aperture.
9 44	move about.
9 45	drink.
9 48	read.
9 50	food aperture.
10 00	count pulse.
10 05	food aperture.
10 10	food aperture.
10 12	urinate, sit, write.
10 55	drink.
11 30	rise, food aperture.
11 32	sit, read.
11 50	drink.
12 00	count pulse.
P. M.	
$12^h\ 02^m$	food aperture.
12 05	food aperture.

Movements of subject—*Continued.*

March 7 (cont.)

P. M.	
12^h 06^m	move about.
12 10	attempt to defecate.
12 12	sit, write.
12 50	drink.
1 02	move about, food aperture, urinate.
1 06	sit, write.
1 08	stand.
1 15	food aperture.
2 00	count pulse.
2 05	drink.
2 16	move about.
2 18	write.
2 28	adjust thermometer.
3 02	move about.
3 04	urinate, sit, read.
3 14	move about.
3 16	food aperture.
3 18	sit, read.
3 20	drink.
4 00	count pulse.
4 05	food aperture.
4 10	move about, urinate.
4 12	sit, read.
5 08	stand.
5 14	move about, stand, doctor count pulse.
5 24	move about.
5 28	read.
5 30	remove coat.
5 34	sit.
5 36	adjust sphygmomanometer.
5 40	remove apparatus, put on coat.
5 42	stand.
5 44	sit.
5 45	drink.
5 46	read.
5 50	food aperture.
5 52	remove thermometer.
5 54	move about.
6 05	sit.
6 07	count pulse.
6 10	food aperture.
6 14	read.
6 40	telephone.
7 01	rise, food aperture.
7 04	sit, read, telephone.
7 08	rise, food aperture.
7 20	rise, move chair, sit.
7 25	drink.
P. M.	
7^h 32^m	rise, urinate, sit.
7 36	rise, food aperture.
8 00	count pulse.
8 04	rise, stand.
8 13	food aperture, sit.
9 02	telephone.
9 35	drink.
9 40	rise, urinate.
10 00	count pulse.
10 10	rise, move about, lower table.
10 12	open bed, read, lie.
10 29	drink.
10 52	asleep.
11 04	rise, urinate, undress.
11 06	close curtain.

March 8.

A. M.	
7^h 02^m	rise, open curtain.
7 04	urinate.
7 05 } 7 09 }	weigh self, etc.
7 10	fold bed.
7 12	dress, raise table, sit.
7 16	comb hair.
7 20	rise, food aperture, sit.
7 32	drink, count pulse.
7 34	telephone.
7 42	food aperture.
7 50	write.
7 55	drink.
8 00	count pulse.
8 04	move about.
8 06	stand, blood sample taken.
8 10	drink.
8 16	move about.
8 20	lean on table, read.
8 26	food aperture.
8 46	sit.
10 00	count pulse.
10 02	move about, urinate.
10 06	sit.
10 12	asleep.
10 54	awake.
10 56	move about.
11 04	asleep.
11 16	food aperture.
11 19	food aperture.
11 24	asleep.
11 26	awake.
11 30	drink.
11 44	food aperture.
11 46	move about.
12 00	count pulse.
P. M.	
12^h 06^m	stand, sit.
12 14	food aperture.
12 28	food aperture.
12 55	drink.
1 42	food aperture, urinate.
2 00	count pulse.
2 06	write.
2 25	drink.
2 42	move about.
2 46	stand, blood sample taken.
3 18	stand.
3 20	food aperture.
3 22	sit.
3 33	drink.
3 40	food aperture.
4 00	count pulse.
4 04	read.
4 50	drink.
5 04	rise, move about.
5 06	stand, doctor count pulse.
5 08	sit.
5 10	move about.
5 12	blood pressure test, coat off.
5 18	put on coat.
5 20	sit.
5 22	read.
5 34	food aperture.
6 00	count pulse.
6 40	drink.
6 48	doze.
6 59	food aperture.
7 04	rise, urinate, telephone, food aperture, sit.
7 32	rise, food aperture.
8 00	count pulse.
8 15	drink.
9 18	telephone, food aperture.
9 55	drink.
10 00	count pulse, food aperture.
10 04	rise, move about.
10 08	lower table, open bed.
10 12	read, lie.
10 14	telephone.
10 16	move about, adjust telephone.
11 02	rise, urinate, undress.
11 04	close curtain.

***Movements of subject*.—Continued.**

March 9.

A. M.	
$7^h\,02^m$	rise, open curtain, urinate.
7 04 7 07	telephone, weigh self, etc.
7 16	dress, raise table, sit, repair telephone.
7 18	food aperture, sit.
7 20	food aperture, repair telephone, comb hair.
7 25	drink.
7 27	food aperture.
7 30	count pulse.
7 50	food aperture.
7 54	read.
8 00	count pulse.
8 10	attempt to defecate.
8 15	drink.
8 16	move about.
8 22	sit.
9 00	move about, drink.
9 04 9 06	stand, blood sampled.
9 11	food aperture.
9 12	read.
9 32	food aperture.
9 34	move about.
9 44	read.
10 00	count pulse.
10 04	food aperture.
10 08	write.
10 45	drink.
11 24	food aperture.
11 28	read.
12 00	count pulse.
P. M.	
$12^h\,02^m$	food aperture.
12 06	read.
12 30	drink.
1 00	rise, urinate, move about.
1 04	food aperture.
1 24	food aperture.
2 00	count pulse.
2 02	read.
3 00	drink.
3 02	move about.
3 06	stand, blood sampled.
3 16	sit, read.
3 36	write.
3 48	asleep.
5 00	awake.
5 02	doze.
5 15	drink.
P. M.	
$5^h\,16^m$	telephone.
5 20	count pulse.
5 26	food aperture.
5 28	stand, doctor count pulse.
5 30	sit, write.
5 32 5 36	coat off, blood pressure test.
5 40	move about, sit, write.
5 46	food aperture.
5 50	read.
6 00	count pulse.
6 14	asleep.
6 40	awake, drink, read.
7 04	food aperture, urinate.
7 10	stand, read, look around.
7 14	rise, telephone, sit.
7 35	write.
7 38	telephone.
7 45	food aperture.
7 50	drink.
8 00	count pulse.
8 35	drink.
9 08	rise, close curtain, attempt to defecate.
9 10	move about, adjust thermometer.
9 12	open curtain.
10 00	count pulse, write.
10 05	drink.
10 06	stand, lower table, open bed, recline, read.
11 04	rise, urinate, undress.
11 06	close curtain.

March 10.

A. M.	
$7^h\,04^m$ 7 10	rise, open curtain, urinate, fold bed, weigh self, etc.
7 14	brush hair, telephone.
7 15	food aperture.
7 25	drink.
7 30	count pulse, write.
7 38	comb hair.
7 52	food aperture.
8 00	count pulse.
8 15	drink.
8 20	read.
9 05	drink.
9 06 9 08	stand, blood sampled, move about.
A. M.	
$9^h\,14^m$	sit, read.
10 00	count pulse.
10 04	food aperture.
10 06	sit.
10 25	drink.
11 02	food aperture, move about.
11 04	sit.
11 22	food aperture.
11 34	drowsy.
11 52	asleep.
12 00	awake, count pulse.
P. M.	
$12^h\,02^m$	food aperture.
12 04	read.
12 15	drink.
12 55	drink.
1 02	move about, food aperture.
1 06	urinate.
1 08	sit.
1 10	remove thermometer.
1 25	write.
1 48	food aperture.
1 53	food aperture.
2 02	write.
2 08	count pulse.
2 18	food aperture.
2 35	drink.
3 02 3 04	stand, blood sampled.
3 10	sit.
3 16	read.
3 32	rise, move about.
4 00	count pulse.
4 10	drink.
4 28	telephone.
4 46	stop telephoning, read.
5 04	telephone.
5 06	stand.
5 08	sit.
5 10	stand, doctor count pulse.
5 12 5 14	blood pressure test.
5 20	put on coat.
5 22	stand, telephone.
5 25	drink.
5 26	food aperture.
5 28	sit, stand, sit.
5 52	read.
6 00	count pulse.
6 10	drink.
7 00	urinate.
7 08	telephone.

Movements of subject.—Continued.

March 10 (cont.)					
P. M.		P. M.		P. M.	
7h 12m	rise, food aperture, telephone, sit.	7h 38m	sit, blood pressure test.	10h 00m	count pulse.
7 24	rise, telephone, move chair, blood pressure test, sit.	7 46	rise, move chair, stand, read.	10 10	drink, rise, lower table, open bed, recline, read.
7 36	rise, move about, telephone.	7 48	food aperture.	11 00	rise, undress, urinate.
		8 05	count pulse.	11 04	close curtain.
		8 12	telephone.		
		9 00	drink.		

Drinking-water.—Table 122 records the daily consumption of water, and the amounts taken in different 2-hour periods. In this experiment the subject measured and recorded the amount of water drunk. The table shows that on different days, there is no uniformity in the amounts of water drunk in any given period. The amounts consumed were less than in the previous fasting experiment. The average for the 7 days was not far from 1800 grams per day.

TABLE 122.—*Record of water consumed*[1]*—Metabolism experiment No. 75.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p.m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	Total for day.
1906.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 4–5....	300.0	313.5	172.7	200.0	193.0	395.8	323.3	75.0	1973.3
Mar. 5–6....	275.0	343.6	326.5	175.0	150.0	172.5	150.0	236.3	1728.9
Mar. 6–7....	396.6	300.0	91.4	50.0	399.7	125.0	293.1	361.8	2117.6
Mar. 7–8....	275.0	393.1	296.0	200.0	193.0	163.1	200.0	191.1	1911.3
Mar. 8–9....	250.0	146.3	394.8	175.0	121.8	138.9	102.3	152.5	1581.6
Mar. 9–10...	300.0	289.5	192.8	....	200.0	328.9	250.0	140.8	1702.0
Mar. 10–11...	300.0	217.8	267.2	150.0	150.0	211.1	125.0	272.0	1693.1

[1] Period during which water was consumed, was assumed in some instances. (See page 73.)

URINE.

The usual method of collecting the urine in four periods was followed. In the samples obtained each period, the weight, specific gravity, reaction, nitrogen, phosphoric acid by titration, and creatinine were determined. The results of these determinations are recorded in table 123. The specific gravity was invariably low and the reaction acid. The agreement between the determinations of nitrogen, phosphoric acid, and creatinine, in the different periods, with the total determined on the daily composite was in all cases very satisfactory. The results recorded in column *g* of the table indicate the amount of preformed creatinine excreted in the urine and do not include the preformed creatine which was subsequently determined and is recorded in table 124, page 178.

Weight, composition, and heat of combustion of urine.—In addition to the determinations made on the samples of urine collected each period, a much larger number of determinations were made on the composite urine for each day. From the percentages thus obtained and the weight of urine, the quantities of elements and compounds excreted have been computed and

TABLE 123.—*Determinations in urine per period and per day—Metabolism experiment No. 75.*

Date and period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a+b).	(d) Reaction.	(e) Nitrogen.	(f) Phosphoric acid by titration (P_2O_5).	(g) Creatinine excreted (preformed)
1905.							
Mar. 4–5:	*Grams.*		*c.c.*		*Grams.*	*Grams.*	*Grams.*
7 a.m. to 1 p.m....	410.9	1.0090	407	Acid.....	4.10	0.383	0.340
1 p.m. 7 p.m....	467.1	1.0059	464	Acid.....	3.30	.394	.330
7 p.m. 11 p.m....	208.7	1.0077	207	Acid.....	1.63	.207	.182
11 p.m. 7 a.m....	421.5	1.0089	418	Acid.....	3.21	.468	.376
Total.............	1508.2	....	1496	....	12.24	1.452	1.228
Total by composite.	1508.2	1.0079	1496	Acid.....	12.20	1.460	1.212
Mar. 5–6:							
7 a.m. to 1 p.m....	777.8	1.0054	774	Acid.....	3.82	.591	.313
1 p.m. 7 p.m....	455.2	1.0097	451	Acid.....	3.30	.802	.256
7 p.m. 11 p.m....	138.9	1.0164	137	Acid.....	1.67	.370	.144
11 p.m. 7 a.m....	513.8	1.0073	509	Acid.....	3.66	.538	.332
Total.............	1885.7	....	1871	....	12.45	2.301	1.045
Total by composite.	1885.7	1.0077	1871	Acid.....	12.40	2.245	1.061
Mar. 6–7:							
7 a.m. to 1 p.m....	503.2	1.0066	500	Acid.....	3.55	.453	.236
1 p.m. 7 p.m....	810.7	1.0040	807	Acid.....	3.73	.635	.222
7 p.m. 11 p.m....	313.6	1.0074	311	Acid.....	2.10	.390	.134
11 p.m. 7 a.m....	593.5	1.0061	590	Acid.....	3.64	.626	.281
Total.............	2221.0	....	2208	....	13.02	2.104	.873
Total by composite.	2221.0	1.0057	2208	Acid.....	12.97	2.091	.956
Mar. 7–8:							
7 a.m. to 1 p.m....	608.9	1.0062	605	Acid.....	3.36	.549	.243
1 p.m. 7 p.m....	821.7	1.0047	818	Acid.....	3.39	.798	.212
7 p.m. 11 p.m....	184.3	1.0129	182	Acid.....	1.68	....	.111
11 p.m. 7 a.m....	384.9	1.0100	381	Acid.....	3.20	.639	.214
Total.............	1999.8	....	1986	....	11.63	....	.780
Total by composite.	1999.8	1.0070	1986	Acid.....	11.63	2.416	.865
Mar. 8–9:							
7 a.m. to 1 p.m....	314.9	1.0147	310	Acid.....	3.19	.549	.169
1 p.m. 7 p.m....	572.2	1.0071	568	Acid.....	3.13	.665	.148
7 p.m. 11 p.m....	177.9	1.0124	176	Acid.....	1.55	.427	.095
11 p.m. 7 a.m....	372.5	1.0095	369	Acid.....	3.00	.550	.237
Total.............	1437.5	....	1423	....	10.87	2.191	.649
Total by composite.	1437.5	1.0100	1423	Acid.....	10.89	2.287	.712
Mar. 9–10:							
7 a.m. to 1 p.m....	453.1	1.0104	448	Acid.....	3.26	.561	.157
1 p.m. 7 p.m....	455.1	1.0080	452	Acid.....	2.82	.578	.158
7 p.m. 11 p.m....	260.6	1.0085	259	Acid.....	1.73	.397	.091
11 p.m. 7 a.m....	455.6	1.0072	452	Acid.....	2.93	.499	.244
Total.............	1624.4	....	1611	....	10.74	2.035	.650
Total by composite.	1624.4	1.0081	1611	Acid.....	10.74	2.062	.733

TABLE 123.—*Determinations in urine per period and per day*—Continued.

Date and period.	(a) Amount	(b) Specific gravity.	(c) Volume ($a+b$).	(d) Reaction.	(e) Nitrogen.	(f) Phosphoric acid by titration (P_2O_5).	(g) Creatinine excreted (preformed)
1905. Mar. 10–11:	*Grams.*		*c. c.*		*Grams.*	*Grams.*	*Grams.*
7 a.m. to 1 p.m....	393.4	1.0111	389	Acid.....	2.98	.522	.148
1 p.m. 7 p.m....	553.2	1.0068	550	Acid.....	2.83	.618	.175
7 p.m. 11 p.m....	228.1	1.0083	227	Acid.....	1.52	....	.119
11 p.m. 7 a.m....	421.8	1.0082	418	Acid.....	2.80	.596	.286
Total..............	1596.5	....	1584	....	10.13	....	.728
Total by composite.	1596.5	1.0080	1584	Acid.....	10.18	1.963	.782
Total, for 7 days...	12273.1	....	12179	....	81.08	....	5.953

recorded in table 124. In addition to the elements and compounds determined in experiment No. 73, inorganic and ethereal sulphur, the so-called neutral sulphur, the preformed creatinine, and creatine were determined. Unfortunately, determinations of uric acid were impracticable. Phosphoric acid was determined both by fusion and titration and the results by both methods are recorded. The phosphorus, sulphur, and chlorine are expressed as phosphoric acid, sulphur trioxide, and sodium chloride, respectively. A few determinations could not be made owing to the quantities or condition of the samples.

ELIMINATION OF WATER-VAPOR.

The elimination of water-vapor was measured in the usual manner. The changes in weight of chair, bedding, and other articles are given as usual in a note at the foot of table 125, page 179. Aside from a slight gain in weight of these articles on March 6, there was a continual loss in weight due to the evaporation of water in the unusually dry atmosphere inside the respiration chamber. The figures given in column *a* show that the amount of moisture in the chamber was considerably less at the end of the experiment than at the beginning.

The total water of respiration and perspiration remained practically constant for the first 3 days of the experiment. On the next 2 days there was a gradual diminution. The lowest elimination was on the sixth day and this was exceeded by only 1 gram on the seventh.

Cutaneous excretion of nitrogenous material.—During the 7 days of this experiment and the 3 days of the food experiment following, the subject eliminated through the skin a total of 0.537 gram of nitrogen, a daily average of 0.054 gram.

TABLE 124.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 75.*

	Mar. 4-5.	Mar. 5-6.	Mar. 6-7.	Mar. 7-8.
(a) Weight....grams..	1508.2	1885.7	2221.0	1999.8
(b) Water....do....	1469.59	1839.88	2175.69	1953.00
(c) Solids, a—b....do....	38.61	45.82	45.31	46.80
(d) Ash....do....	6.03	7.54	6.44	7.80
(e) Organic matter, c—d....do....	32.58	38.28	38.87	39.00
(f) Nitrogen....do....	12.24	12.45	13.02	11.63
(g) Carbon....do....	8.14	11.50	11.11	12.20
(h) Hydrogen in organic matter....do....	2.26	2.83	2.89	2.80
(i) Oxygen (by difference) in organic matter, e—(f+g+h)....grams..	9.94	11.50	11.85	12.37
(j) Phosphorus....do....	.625	.984	.897	1.051
Phosphoric acid (P_2O_5):				
(k) By fusion....grams..	1.431	2.255	2.055	2.406
(l) By titration....do....	1.460	2.245	2.091	2.416
(m) Sulphur....do....	.625	.669	.749	.722
Sulphur trioxide (SO_3):				
(n) Total....grams..	1.559	1.669	1.871	1.802
(o) Inorganic and ethereal....do....	1.354	1.480	....[1]	1.618
(p) Neutral, n—o....do....	.205	.189	....[1]	.184
(q) Creatinine (preformed)....do....	1.212	1.061	.956	.865
(r) Total creatinine....do....	1.237	1.294	1.407	1.325
(s) Creatine[2] (preformed), r—q....do....	.025	.233	.551	.460
(t) Chlorine....do....	1.447	1.338	.616	.245
(u) Sodium chloride....do....	2.388	2.208	1.016	.405
(v) Heat of combustion....calories..	97	136	138	146

	Mar. 8-9.	Mar. 9-10.	Mar. 10-11.	Total for 7 days.
(a) Weight....grams..	1437.5	1624.4	1596.5	12,273.1
(b) Water....do....	1391.64	1580.70	1553.08	11,963.58
(c) Solids, a—b....do....	45.86	43.70	43.42	309.52
(d) Ash....do....	7.48	5.85	5.27	46.41
(e) Organic matter, c—d....do....	38.38	37.85	38.15	263.11
(f) Nitrogen....do....	10.87	10.74	10.13	81.08
(g) Carbon....do....	12.65	12.02	11.34	78.96
(h) Hydrogen in organic matter....do....	2.73	2.60	2.71	18.82
(i) Oxygen (by difference) in organic matter, e—(f+g+h)....grams..	12.13	12.49	13.97	84.25
(j) Phosphorus....do....	.907	.904	.909	6.277
Phosphoric acid (P_2O_5):				
(k) By fusion....grams..	2.078	2.071	2.080	14.376
(l) By titration....do....	2.287	2.062	1.963	14.524
(m) Sulphur....do....	.668	.660	.622	4.715
Sulphur trioxide (SO_3):				
(n) Total....grams..	1.668	1.648	1.553	11.770
(o) Inorganic and ethereal....do....	1.519	1.477	1.414	....
(p) Neutral, n—o....do....	.149	.171	.139	....
(q) Creatinine (preformed)....do....	.712	.733	.782	6.321
(r) Total creatinine....do....	1.214	1.318	1.270	9.065
(s) Creatine[2] (preformed), r—q....do....	.502	.585	.488	2.844
(t) Chlorine....do....	....[1]	.387	.420	....
(u) Sodium chloride....do....	....[1]	.638	.694	....
(v) Heat of combustion....calories..	147	146	139	949

[1] Not determined. [2] In terms of creatinine.

TABLE 125.—*Record of water of respiration and perspiration—Metabolism experiment No. 75.*

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905.		
Mar. 4:		
Preliminary:	*Grams.*	*Grams.*
1 a.m.	46.1	....
1 a.m. to 3 a.m.	46.0	98.2
3 a.m. 5 a.m.	43.8	91.4
5 a.m. 7 a.m.	38.2	84.5
Total	....	274.1
Mar. 4–5:		
7 a.m. to 9 a.m.	36.9	72.6
9 a.m. 11 a.m.	31.4	62.4
11 a.m. 1 p.m.	29.9	55.9
1 p.m. 3 p.m.	26.8	51.2
3 p.m. 5 p.m.	26.5	47.4
5 p.m. 7 p.m.	25.6	47.5
7 p.m. 9 p.m.	26.2	48.9
9 p.m. 11 p.m.	27.6	54.0
11 p.m. 1 a.m.	27.7	51.3
1 a.m. 3 a.m.	26.3	50.6
3 a.m. 5 a.m.	27.3	53.7
5 a.m. 7 a.m.	27.8	54.6
Total	....	650.1
Mar. 5–6:		
7 a.m. to 9 a.m.	32.8	74.2
9 a.m. 11 a.m.	27.9	58.8
11 a.m. 1 p.m.	25.6	51.7
1 p.m. 3 p.m.	24.4	50.6
3 p.m. 5 p.m.	23.3	50.0
5 p.m. 7 p.m.	24.6	49.9
7 p.m. 9 p.m.	24.1	50.4
9 p.m. 11 p.m.	25.1	52.6
11 p.m. 1 a.m.	23.2	49.7
1 a.m. 3 a.m.	25.5	53.6
3 a.m. 5 a.m.	24.0	48.2
5 a.m. 7 a.m.	25.3	52.4
Total	....	642.1
Mar. 6–7:		
7 a.m. to 9 a.m.	30.0	68.0
9 a.m. 11 a.m.	28.5	58.2
11 a.m. 1 p.m.	26.9	45.4
1 p.m. 3 p.m.	26.0	58.1
3 p.m. 5 p.m.	26.4	53.4
5 p.m. 7 p.m.	25.5	53.8
7 p.m. 9 p.m.	25.4	54.2
9 p.m. 11 p.m.	23.8	54.2
11 p.m. 1 a.m.	23.4	51.2
1 a.m. 3 a.m.	24.9	54.4
1905.		
Mar. 6–7:	*Grams.*	*Grams.*
3 a.m. 5 a.m.	25.1	54.1
5 a.m. 7 a.m.	24.0	52.8
Total	....	657.8
Mar. 7–8:		
7 a.m. to 9 a.m.	25.5	52.8
9 a.m. 11 a.m.	25.6	47.6
11 a.m. 1 p.m.	25.6	51.1
1 p.m. 3 p.m.	25.4	52.1
3 p.m. 5 p.m.	23.6	48.3
5 p.m. 7 p.m.	25.9	51.1
7 p.m. 9 p.m.	20.6	48.8
9 p.m. 11 p.m.	23.7	52.9
11 p.m. 1 a.m.	23.8	50.3
1 a.m. 3 a.m.	23.0	46.4
3 a.m. 5 a.m.	22.1	48.9
5 a.m. 7 a.m.	22.3	45.8
Total	....	596.1
Mar. 8–9:		
7 a.m. to 9 a.m.	25.3	56.3
9 a.m. 11 a.m.	24.8	45.9
11 a.m. 1 p.m.	23.7	50.4
1 p.m. 3 p.m.	23.8	49.4
3 p.m. 5 p.m.	23.4	47.2
5 p.m. 7 p.m.	23.1	45.7
7 p.m. 9 p.m.	22.1	48.3
9 p.m. 11 p.m.	23.3	49.3
11 p.m. 1 a.m.	21.8	45.4
1 a.m. 3 a.m.	22.0	47.4
3 a.m. 5 a.m.	22.2	49.4
5 a.m. 7 a.m.	22.3	44.6
Total	....	579.3
Mar. 9–10:		
7 a.m. to 9 a.m.	23.9	54.1
9 a.m. 11 a.m.	24.1	48.5
11 a.m. 1 p.m.	21.9	46.8
1 p.m. 3 p.m.	21.2	44.8
3 p.m. 5 p.m.	20.1	38.9
5 p.m. 7 p.m.	21.0	43.0
7 p.m. 9 p.m.	20.4	44.5
9 p.m. 11 p.m.	21.0	44.7
11 p.m. 1 a.m.	20.7	43.4
1 a.m. 3 a.m.	21.6	45.2
3 a.m. 5 a.m.	20.8	43.6
5 a.m. 7 a.m.	20.4	44.4
Total	....	541.9

[1] Allowance has been made for water gained or lost by chair, bedding, and miscellaneous articles as follows: March 4-5, 88.53 grams lost; March 5-6, 86.43 grams lost; March 6-7, 1.13 grams gained; March 7-8, 20.74 grams lost; March 8-9, 11.42 grams lost; March 9-10, 17.15 grams lost.

TABLE 125.—*Record of water of respiration and perspiration*—Continued.

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]	Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905. Mar. 10–11:	*Grams.*	*Grams.*	1905. Mar. 10–11:	*Grams.*	*Grams.*
7 a.m. to 9 a.m.	24.2	55.1	9 p.m. to 11 p.m.	21.3	45.1
9 a.m. 11 a.m.	22.9	44.3	11 p.m. 1 a.m.	21.4	45.4
11 a.m. 1 p.m.	22.0	46.5	1 a.m. 3 a.m.	19.9	42.4
1 p.m. 3 p.m.	21.2	47.3	3 a.m. 5 a.m.	21.5	47.1
3 p.m. 5 p.m.	21.8	44.2	5 a.m. 7 a.m.	20.7	44.4
5 p.m. 7 p.m.	22.4	43.1	Total	....	542.9
7 p.m. 9 p.m.	24.9	38.0			

[1] Allowance has been made for water gained or lost by chair, bedding, and miscellaneous articles as follows: March 10-11, 8.94 grams lost.

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The data for the carbon dioxide and oxygen recorded in table 126 show the usual fluctuations in the residual amounts of these gases. The variations in the elimination of carbon dioxide from day to day were nearly paralleled by those observed in the absorption of oxygen, the largest amounts of carbon dioxide exhaled and oxygen consumed being observed on the first 3 days. After the third day there was a steady diminution until constancy was reached on the last 2 days. On the last day about 95 grams less carbon dioxide were given off than on the first day, and about 70 grams less oxygen were consumed.

TABLE 126.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 75.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1905.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Mar. 4	1 a.m.	24.6	....	928.8	....
	1 a.m. to 3 a.m.	19.7	39.4	922.8	35.7
	3 a.m. 5 a.m.	20.4	44.2	919.6	34.4
	5 a.m. 7 a.m.	21.2	46.4	924.7	35.1
	Total	....	130.0	.....	105.2
Mar. 4–5	7 a.m. to 9 a.m.	27.1	62.7	924.0	54.6
	9 a.m. 11 a.m.	24.3	56.0	928.0	44.2
	11 a.m. 1 p.m.	24.4	50.1	927.4	45.5
	1 p.m. 3 p.m.	21.6	46.8	935.6	39.9
	3 p.m. 5 p.m.	22.7	45.0	930.7	66.9
	5 p.m. 7 p.m.	22.8	49.3	957.5	42.7
	7 p.m. 9 p.m.	21.7	47.0	969.3	45.8
	9 p.m. 11 p.m.	22.1	50.2	973.5	47.8
	11 p.m. 1 a.m.	18.4	39.5	981.7	30.6
	1 a.m. 3 a.m.	16.5	38.2	987.6	34.7
	3 a.m. 5 a.m.	19.6	42.5	986.8	39.8
	5 a.m. 7 a.m.	19.1	42.6	989.7	41.1
	Total	....	569.9	.....	533.6

TABLE 126.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Mar. 5–6......	7 a.m. to 9 a.m...	25.5	59.2	980.3	67.7
	9 a.m. 11 a.m...	23.3	52.3	985.7	41.3
	11 a.m. 1 p.m...	24.8	48.8	979.0	44.3
	1 p.m. 3 p.m...	22.2	46.4	971.4	46.6
	3 p.m. 5 p.m...	21.1	44.4	969.0	39.9
	5 p.m. 7 p.m...	22.1	48.3	962.5	44.6
	7 p.m. 9 p.m...	20.6	46.4	966.2	42.1
	9 p.m. 11 p.m...	20.8	47.6	962.5	48.4
	11 p.m. 1 a.m...	16.4	37.4	969.3	29.7
	1 a.m. 3 a.m...	15.9	37.9	957.1	40.0
	3 a.m. 5 a.m...	17.6	39.4	962.3	52.7
	5 a.m. 7 a.m...	18.9	42.5	966.8	37.0
	Total...........	....	550.6	.....	534.3
Mar. 6–7......	7 a.m. to 9 a.m...	24.6	55.2	968.0	59.9
	9 a.m. 11 a.m...	24.4	54.8	974.1	51.5
	11 a.m. 1 p.m...	25.9	48.6	976.5	43.4
	1 p.m. 3 p.m...	22.8	50.2	979.6	48.7
	3 p.m. 5 p.m...	25.5	49.6	982.8	50.6
	5 p.m. 7 p.m...	22.6	48.6	989.0	49.6
	7 p.m. 9 p.m...	23.5	46.3	994.0	44.7
	9 p.m. 11 p.m...	20.7	45.2	999.2	43.2
	11 p.m. 1 a.m...	17.6	34.0	999.5	29.3
	1 a.m. 3 a.m...	15.8	35.7	998.9	34.4
	3 a.m. 5 a.m...	19.6	38.5	995.0	39.9
	5 a.m. 7 a.m...	18.1	38.4	993.8	40.5
	Total..........	....	545.1	.....	535.7
Mar. 7–8.....	7 a.m. to 9 a.m...	25.8	51.8	992.0	53.3
	9 a.m. 11 a.m...	24.8	49.9	977.5	46.3
	11 a.m. 1 p.m...	29.0	51.9	965.4	49.5
	1 p.m. 3 p.m...	23.2	49.3	960.8	50.5
	3 p.m. 5 p.m...	25.5	46.4	952.0	45.4
	5 p.m. 7 p.m...	24.8	54.0	939.6	51.8
	7 p.m. 9 p.m...	24.1	44.1	939.8	36.1
	9 p.m. 11 p.m...	19.9	43.8	925.4	50.7
	11 p.m. 1 a.m...	20.5	36.8	912.4	33.5
	1 a.m. 3 a.m...	15.6	31.6	902.9	30.9
	3 a.m. 5 a.m...	16.2	36.0	898.9	38.5
	5 a.m. 7 a.m...	17.8	38.6	891.8	33.1
	Total..........	....	534.2	.....	519.6
Mar. 8–9.....	7 a.m. to 9 a.m...	24.3	52.8	881.1	55.1
	9 a.m. 11 a.m...	21.6	43.7	882.7	38.5
	11 a.m. 1 p.m...	25.5	46.8	864.1	49.6
	1 p.m. 3 p.m...	22.2	45.9	861.3	43.2
	3 p.m. 5 p.m...	24.8	45.1	861.0	44.7
	5 p.m. 7 p.m...	21.2	44.5	865.5	39.9
	7 p.m. 9 p.m...	22.7	39.8	868.8	39.0
	9 p.m. 11 p.m...	19.2	41.5	869.8	44.3
	11 p.m. 1 a.m...	20.5	34.4	879.4	28.6
	1 a.m. 3 a.m...	16.2	32.1	887.6	31.8
	3 a.m. 5 a.m...	16.2	33.3	895.6	36.3
	5 a.m. 7 a.m...	17.9	36.5	895.1	40.0
	Total..........	....	496.4	.....	491.0

TABLE 126.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Mar. 9–10....	7 a. m. to 9 a. m...	23.1	49.9	894.4	45.9
	9 a. m. 11 a. m...	21.5	45.4	884.6	46.8
	11 a. m. 1 p. m...	22.4	41.8	886.3	42.3
	1 p. m. 3 p. m...	18.4	41.3	877.7	38.0
	3 p. m. 5 p. m...	22.2	37.1	870.9	35.5
	5 p. m. 7 p. m...	19.6	41.7	862.6	45.4
	7 p. m. 9 p. m...	24.0	40.5	853.3	38.9
	9 p. m. 11 p. m...	20.2	44.5	842.6	42.0
	11 p. m. 1 a. m...	22.0	33.2	833.5	34.1
	1 a. m. 3 a. m...	15.6	32.0	830.0	28.0
	3 a. m. 5 a. m...	21.8	33.9	829.4	33.3
	5 a. m. 7 a. m...	17.3	36.1	831.2	35.9
	Total..........	....	477.4	.....	466.1
Mar. 10–11...	7 a. m. to 9 a. m...	29.0	48.7	818.4	50.3
	9 a. m. 11 a. m...	21.5	42.5	825.2	44.6
	11 a. m. 1 p. m...	27.5	39.6	826.2	35.3
	1 p. m. 3 p. m...	20.1	44.8	826.7	42.3
	3 p. m. 5 p. m...	28.6	41.1	821.6	39.2
	5 p. m. 7 p. m...	21.3	44.5	827.9	45.1
	7 p. m. 9 p. m...	37.1	43.2	828.8	40.0
	9 p. m. 11 p. m...	20.5	37.9	848.3	39.3
	11 p. m. 1 a. m...	24.6	32.2	853.9	30.5
	1 a. m. 3 a. m...	15.2	30.4	869.9	30.6
	3 a. m. 5 a. m...	23.7	33.9	871.7	33.0
	5 a. m. 7 a. m...	16.9	36.8	887.8	36.2
	Total..........	....	475.6	.....	466.4

ELEMENTS AND MATERIALS KATABOLIZED IN THE BODY.

The elements katabolized in the body are given in table 127, page 183. In table 128, page 184, the results obtained by computing the amounts of body materials corresponding to these elements are shown. As in the majority of other experiments without food, the loss of carbohydrates was greatest on the first day, though much smaller than that usually observed for this particular day. Contrary to the results of experiment No. 73, the loss in glycogen is persistent, continuing through the whole 7 days of the experiment.

Balance of water.—Table 129, page 185, shows the usual data regarding intake and outgo of water.

TABLE 127.—*Elements katabolized in body—Metabolism experiment No. 75.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Mar. 4, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	533.62	....	....	....	533.62	....
Outgo:						
Water in urine	1469.59	....	....	164.45	1305.14	....
Solids in urine	38.61	12.24	8.14	2.26	9.94	6.03
Water of respiration [1]	650.11	....	....	72.75	577.36	....
Carbon dioxide	569.93	....	155.45	....	414.48	....
Total	2728.24	12.24	163.59	239.46	2306.92	6.03
Loss	2194.62	12.24	163.59	239.46	1773.30	6.03
Second day, Mar. 5, 1905.						
Income: Oxygen from air	534.30	....	....	....	534.30	....
Outgo:						
Water in urine	1839.88	....	....	205.88	1634.00	....
Solids in urine	45.82	12.45	11.50	2.83	11.50	7.54
Water of respiration [1]	642.09	....	....	71.85	570.24	....
Carbon dioxide	550.63	....	150.17	....	400.46	....
Total	3078.42	12.45	161.67	280.56	2616.20	7.54
Loss	2544.12	12.45	161.67	280.56	2081.90	7.54
Third day, Mar. 6, 1905.						
Income: Oxygen from air	535.73	....	....	....	535.73	....
Outgo:						
Water in urine	2175.69	....	....	243.46	1932.23	....
Solids in urine	45.31	13.02	11.11	2.89	11.85	6.44
Water of respiration [1]	657.84	....	....	73.61	584.23	....
Carbon dioxide	545.08	....	148.66	....	396.42	....
Total	3423.92	13.02	159.77	319.96	2924.73	6.44
Loss	2888.19	13.02	159.77	319.96	2389.00	6.44
Fourth day, Mar. 7, 1905.						
Income: Oxygen from air	519.54	....	....	....	519.54	....
Outgo:						
Water in urine	1953.00	....	....	218.54	1734.46	....
Solids in urine	46.80	11.63	12.20	2.80	12.37	7.80
Water of respiration [1]	596.13	....	....	66.71	529.42	....
Carbon dioxide	534.24	....	145.71	....	388.53	....
Total	3130.17	11.63	157.91	288.05	2664.78	7.80
Loss	2610.63	11.63	157.91	288.05	2145.24	7.80
Fifth day, Mar. 8, 1905.						
Income: Oxygen from air	491.04	....	....	....	491.04	....
Outgo:						
Water in urine	1391.64	....	....	155.72	1235.92	....
Solids in urine	45.86	10.87	12.65	2.73	12.13	7.48
Water of respiration [1]	579.29	....	....	64.82	514.47	....
Carbon dioxide	496.38	....	135.39	....	360.99	....
Total	2513.17	10.87	148.04	223.27	2123.51	7.48
Loss	2022.13	10.87	148.04	223.27	1632.47	7.48

[1] Includes also water of perspiration.

TABLE 127.—*Elements katabolized in body*—Continued.

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
Sixth day, Mar. 9, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	466.06	....	....	....	466.06	....
Outgo:						
Water in urine	1580.70	....	....	176.88	1403.82	....
Solids in urine	43.70	10.74	12.02	2.60	12.49	5.85
Water of respiration[1]	541.90	....	....	60.64	481.26	....
Carbon dioxide	477.40	....	130.21	....	347.19	....
Total	2643.70	10.74	142.23	240.12	2244.76	5.85
Loss	2177.64	10.74	142.23	240.12	1778.70	5.85
Seventh day, Mar. 10, 1905.						
Income: Oxygen from air	466.38	....	....	....	466.38	....
Outgo:						
Water in urine	1553.08	....	....	173.79	1379.29	....
Solids in urine	43.42	10.13	11.34	2.71	13.97	5.27
Water of respiration[1]	542 85	....	....	60.74	482.11	....
Carbon dioxide	475.55	....	129.70	....	345.85	....
Total	2614.90	10.13	141.04	237.24	2221.22	5.27
Loss	2148.52	10.13	141.04	237.24	1754.84	5.27

[1] Includes also water of perspiration.

TABLE 128.—*Elements and materials katabolized in body—Metabolism experiment No. 75.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 4–5	12.24	163.59	239.46	1,773.30	1,924.97	73.44	126.40	64.90	6.03
Mar. 5–6	12.45	161.67	280.56	2,081.90	2,202.48	74.70	147.45	23.09	7.54
Mar. 6–7	13.02	159.77	319.96	2,389.00	2,646.48	78.12	152.96	5.39	6.44
Mar. 7–8	11.63	157.91	288.05	2,145.24	2,364.23	69.78	144.72	25.17	7.80
Mar. 8–9	10.87	148.04	223.27	1,632.47	1,797.50	65.22	144.73	8.20	7.48
Mar. 9–10	10.74	142.23	240.12	1,778.70	1,956.86	64.44	129.81	21.67	5.85
Mar. 10–11	10.13	141.04	237.24	1,754.84	1,932.20	60.78	132.53	18.67	5.27
T'l, 7 days.	81.08	1047.25	1828.66	13,555.45	14,914.72	486.48	978.60	167.09	46.41

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

The difficulties previously mentioned, which had interfered somewhat in the weighing of the subject and articles in the chamber, were largely overcome by experience. This experience resulted in an extremely satisfactory balance between the actual losses in body-weight and the differences between the income and outgo.

In considering the outgo, 48.40 grams of fresh feces passed on the first day of the experiment but belonging to the food eaten before the experiment have not been taken into consideration. For explanation of this omission, see page 120. The apparent discrepancies between the amounts of urine as recorded in line *d* of table 130 and column *a* of table 123 have also been explained for the corresponding table of experiment No. 68, page 66.

Comparing the losses in weight obtained by the two methods, we have for the first time what may be said to be a satisfactory agreement, the total discrepancy for the 7 days being less than 2 grams. It is furthermore to be noted that the agreement on all individual days is very satisfactory.

TABLE 129.—*Distribution of intake and outgo of water—Metabolism experiment No. 75.*

Date.	Outgo from the body.			Balance of preformed water.			(g)
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.	(e) Intake in drink.	(f) Loss of preformed water (d−e).	Water of oxidation of organic hydrogen (c−d).
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 4–5	1469.6	650.1	2119.7	[1]1925.0	1973.3	[2]−48.3	194.7
Mar. 5–6	1839.9	642.1	2482.0	2292.5	1728.9	563.6	189.5
Mar. 6–7	2175.7	657.8	2833.5	2646.5	2117.6	528.9	187.0
Mar. 7–8	1953.0	596.1	2549.1	2364.2	1911.3	452.9	184.9
Mar. 8–9	1391.6	579.3	1970.9	1797.5	1581.6	215.9	173.4
Mar. 9–10	1580.7	541.9	2122.6	1956.9	1702.0	254.9	165.7
Mar. 10–11	1553.1	542.9	2096.0	1932.2	1693.1	239.1	163.8
Total, 7 days	11963.6	4210.2	16173.8	14914.7	12707.8	2206.9	1259.1
Average per day	1709.1	601.5	2310.6	2130.7	1815.4	315.3	179.9

[1] Does not include water of feces. [2] Gain. Water of feces not taken into account.

TABLE 130.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 75.*

	Mar. 4–5.	Mar. 5–6.	Mar. 6–7.	Mar. 7–8.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(a) Water consumed	1973.30	1728.90	2117.60	1911.30
(b) Oxygen	533.62	534.30	535.73	519.54
(c) Total (a+b)	2506.92	2263.20	2653.33	2430.84
Outgo:				
(d) Urine[1]	1816.40	1793.40	2141.30	2208.40
(e) Feces[2]	48.40	....	....	....
(f) Carbon dioxide	569.93	550.63	545.08	534.24
(g) Water of respiration and perspiration	650.11	642.09	657.84	596.13
(h) Total (d+f+g)	2536.44	2986.12	3344.22	3338.77
(i) Loss of body material	29.52	722.92	690.89	907.93
(j) Loss of body-weight	44.00	723.00	685.00	894.00

	Mar. 8–9.	Mar. 9–10.	Mar. 10–11.	Total for 7 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(a) Water consumed	1581.60	1702.00	1693.10	12,707.80	1815.40
(b) Oxygen	491.04	466.06	466.38	3,546.67	506.67
(c) Total (a+b)	2072.64	2168.06	2159.48	16,254.47	2322.07
Outgo:					
(d) Urine[1]	1449.90	1541.30	1630.30	12,081.00	1725.86
(e) Feces[2]	....	....	....	48.40	6.91
(f) Carbon dioxide	496.38	477.40	475.55	3,649.21	521.31
(g) Water of respiration and perspiration	579.29	541.90	542.85	4,210.21	601.46
(h) Total (d+f+g)	2525.57	2560.60	2648.70	19,940.42	2848.63
(i) Loss of body material	452.93	392.54	489.22	3,685.95	526.56
(j) Loss of body-weight	450.00	391.00	497.00	3,684.00	526.29

[1] The data in this line should not be confounded with urine data in other tables. See explanation, p. 63.
[2] Not included in the total outgo. See p. 120.

OUTPUT OF HEAT.

The total heat production for this experiment is recorded in table 131. The total heat production remained nearly constant for the first 4 days. On the fifth day it is over 100 calories less than on any preceding day, and on the last 2 days it was practically constant at about 1560 calories.

TABLE 131.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 75.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 4	1 a.m. to 3 a.m.	80.6	58.1	[2]− 3.0	[2]135.7
	3 a.m. 5 a.m.	76.4	54.2	[2]− 1.2	[2]129.4
	5 a.m. 7 a.m.	71.4	50.0	[2]−12.6	[2]108.8
	Total	228.4	162.3	[2]−16.8	[2]373.9
Mar. 4–5	7 a.m. to 9 a.m.	169.2	47.3	−26.2	190.3
	9 a.m. 11 a.m.	132.6	41.3	+ 2.2	176.1
	11 a.m. 1 p.m.	116.3	37.5	+12.1	165.9
	1 p.m. 3 p.m.	111.8	34.7	− 8.4	138.1
	3 p.m. 5 p.m.	109.4	32.4	+ 6.2	148.0
	5 p.m. 7 p.m.	114.4	32.5	+ 2.5	149.4
	7 p.m. 9 p.m.	113.4	33.3	+ 2.7	149.4
	9 p.m. 11 p.m.	128.0	36.4	−13.6	150.8
	11 p.m. 1 a.m.	47.8	34.8	+14.5	97.1
	1 a.m. 3 a.m.	82.4	34.3	− 6.0	110.7
	3 a.m. 5 a.m.	94.8	36.2	+21.5	152.5
	5 a.m. 7 a.m.	82.4	36.6	+17.6	136.6
	Total	1302.5	437.3	+25.1	1764.9
Mar. 5–6	7 a.m. to 9 a.m.	186.2	45.7	−37.0	194.9
	9 a.m. 11 a.m.	137.9	36.6	+ 7.9	182.4
	11 a.m. 1 p.m.	117.5	32.4	+ 9.6	159.5
	1 p.m. 3 p.m.	113.8	31.8	+ 7.2	152.8
	3 p.m. 5 p.m.	115.2	31.4	− 6.6	140.0
	5 p.m. 7 p.m.	122.6	31.3	+10.4	164.3
	7 p.m. 9 p.m.	117.8	31.6	− 8.2	141.2
	9 p.m. 11 p.m.	140.2	32.9	−36.6	136.5
	11 p.m. 1 a.m.	65.2	31.2	+19.4	115.8
	1 a.m. 3 a.m.	62.4	33.6	+38.5	134.5
	3 a.m. 5 a.m.	90.1	30.3	− 7.0	113.4
	5 a.m. 7 a.m.	80.8	32.8	+19.1	132.7
	Total	1349.7	401.6	+16.7	1768.0
Mar. 6–7	7 a.m. to 9 a.m.	174.5	40.3	−26.8	188.0
	9 a.m. 11 a.m.	141.9	34.4	+11.5	187.8
	11 a.m. 1 p.m.	123.1	26.9	− 2.6	147.4
	1 p.m. 3 p.m.	136.8	34.4	+ 5.9	177.1
	3 p.m. 5 p.m.	130.9	31.6	+ 5.4	167.9
	5 p.m. 7 p.m.	130.4	31.8	+ 4.6	166.8
	7 p.m. 9 p.m.	123.4	32.1	− 6.5	149.0
	9 p.m. 11 p.m.	126.5	32.1	−20.3	138.3
	11 p.m. 1 a.m.	53.0	30.3	+ 6.4	89.7
	1 a.m. 3 a.m.	69.6	32.2	+22.3	124.1
	3 a.m. 5 a.m.	97.6	32.0	+ 8.5	138.1
	5 a.m. 7 a.m.	91.1	30.6	+ 0.9	122.6
	Total	1398.8	388.7	+ 9.3	1796.8

[1] See pp. 42-49. [2] Not corrected for changes in body temperature and weight.

TABLE 131.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 7–8	7 a.m. to 9 a.m.	162.7	32.3	− 9.9	185.1
	9 a.m. 11 a.m.	123.1	29.2	+10.5	162.8
	11 a.m. 1 p.m.	129.5	31.3	+10.7	171.5
	1 p.m. 3 p.m.	122.4	31.8	+ 8.0	162.2
	3 p.m. 5 p.m.	123.5	29.6	− 0.5	152.6
	5 p.m. 7 p.m.	140.7	31.3	− 3.0	169.0
	7 p.m. 9 p.m.	121.7	29.9	− 9.4	142.2
	9 p.m. 11 p.m.	124.8	32.4	−18.8	138.4
	11 p.m. 1 a.m.	58.6	30.8	+21.3	110.7
	1 a.m. 3 a.m.	76.3	28.5	+ 5.6	110.4
	3 a.m. 5 a.m.	98.5	30.0	+12.9	141.4
	5 a.m. 7 a.m.	85.4	28.1	+15.5	129.0
	Total	1367.2	365.2	+42.9	1775.3
Mar. 8–9	7 a.m. to 9 a.m.	153.2	33.9	−24.7	162.4
	9 a.m. 11 a.m.	121.0	27.7	+10.4	159.1
	11 a.m. 1 p.m.	120.4	30.4	+ 5.4	156.2
	1 p.m. 3 p.m.	114.3	29.8	+ 8.1	152.2
	3 p.m. 5 p.m.	122.3	28.5	− 5.0	145.8
	5 p.m. 7 p.m.	120.9	27.6	+ 6.8	155.3
	7 p.m. 9 p.m.	108.3	29.2	− 2.2	135.3
	9 p.m. 11 p.m.	118.3	29.7	−21.9	126.1
	11 p.m. 1 a.m.	57.6	27.4	+15.0	100.0
	1 a.m. 3 a.m.	69.2	28.7	+ 6.1	104.0
	3 a.m. 5 a.m.	95.0	29.8	+ 9.8	134.6
	5 a.m. 7 a.m.	71.3	27.0	+19.7	118.0
	Total	1271.8	349.7	+27.5	1649.0
Mar. 9–10	7 a.m. to 9 a.m.	147.9	32.9	−19.7	161.1
	9 a.m. 11 a.m.	120.9	29.5	+12.3	162.7
	11 a.m. 1 p.m.	112.2	28.5	− 0.3	140.4
	1 p.m. 3 p.m.	112.3	27.4	− 2.3	137.4
	3 p.m. 5 p.m.	96.3	23.9	+ 1.5	121.7
	5 p.m. 7 p.m.	112.9	26.3	+11.6	150.8
	7 p.m. 9 p.m.	108.8	27.2	−16.0	120.0
	9 p.m. 11 p.m.	114.3	27.3	−20.7	120.9
	11 p.m. 1 a.m.	52.2	26.6	+25.5	104.3
	1 a.m. 3 a.m.	69.4	27.6	−12.0	85.0
	3 a.m. 5 a.m.	83.9	26.6	+12.1	122.6
	5 a.m. 7 a.m.	71.6	27.1	+27.2	125.9
	Total	1202.7	330.9	+19.2	1552.8

[1] See pp. 42-49.

OUTPUT OF HEAT.

The total heat production for this experiment is recorded in table 131. The total heat production remained nearly constant for the first 4 days. On the fifth day it is over 100 calories less than on any preceding day, and on the last 2 days it was practically constant at about 1560 calories.

TABLE 131.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 75.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 4	1 a.m. to 3 a.m.	80.6	58.1	[2]− 3.0	[2]135.7
	3 a.m. 5 a.m.	76.4	54.2	[2]− 1.2	[2]129.4
	5 a.m. 7 a.m.	71.4	50.0	[2]−12.6	[2]108.8
	Total	228.4	162.3	[2]−16.8	[2]373.9
Mar. 4–5	7 a.m. to 9 a.m.	169.2	47.3	−26.2	190.3
	9 a.m. 11 a.m.	132.6	41.3	+ 2.2	176.1
	11 a.m. 1 p.m.	116.3	37.5	+12.1	165.9
	1 p.m. 3 p.m.	111.8	34.7	− 8.4	138.1
	3 p.m. 5 p.m.	109.4	32.4	+ 6.2	148.0
	5 p.m. 7 p.m.	114.4	32.5	+ 2.5	149.4
	7 p.m. 9 p.m.	113.4	33.3	+ 2.7	149.4
	9 p.m. 11 p.m.	128.0	36.4	−13.6	150.8
	11 p.m. 1 a.m.	47.8	34.8	+14.5	97.1
	1 a.m. 3 a.m.	82.4	34.3	− 6.0	110.7
	3 a.m. 5 a.m.	94.8	36.2	+21.5	152.5
	5 a.m. 7 a.m.	82.4	36.6	+17.6	136.6
	Total	1302.5	437.3	+25.1	1764.9
Mar. 5–6	7 a.m. to 9 a.m.	186.2	45.7	−37.0	194.9
	9 a.m. 11 a.m.	137.9	36.6	+ 7.9	182.4
	11 a.m. 1 p.m.	117.5	32.4	+ 9.6	159.5
	1 p.m. 3 p.m.	113.8	31.8	+ 7.2	152.8
	3 p.m. 5 p.m.	115.2	31.4	− 6.6	140.0
	5 p.m. 7 p.m.	122.6	31.3	+10.4	164.3
	7 p.m. 9 p.m.	117.8	31.6	− 8.2	141.2
	9 p.m. 11 p.m.	140.2	32.9	−36.6	136.5
	11 p.m. 1 a.m.	65.2	31.2	+19.4	115.8
	1 a.m. 3 a.m.	62.4	33.6	+38.5	134.5
	3 a.m. 5 a.m.	90.1	30.3	− 7.0	113.4
	5 a.m. 7 a.m.	80.8	32.8	+19.1	132.7
	Total	1349.7	401.6	+16.7	1768.0
Mar. 6–7	7 a.m. to 9 a.m.	174.5	40.3	−26.8	188.0
	9 a.m. 11 a.m.	141.9	34.4	+11.5	187.8
	11 a.m. 1 p.m.	123.1	26.9	− 2.6	147.4
	1 p.m. 3 p.m.	136.8	34.4	+ 5.9	177.1
	3 p.m. 5 p.m.	130.9	31.6	+ 5.4	167.9
	5 p.m. 7 p.m.	130.4	31.8	+ 4.6	166.8
	7 p.m. 9 p.m.	123.4	32.1	− 6.5	149.0
	9 p.m. 11 p.m.	126.5	32.1	−20.3	138.3
	11 p.m. 1 a.m.	53.0	30.3	+ 6.4	89.7
	1 a.m. 3 a.m.	69.6	32.2	+22.3	124.1
	3 a.m. 5 a.m.	97.6	32.0	+ 8.5	138.1
	5 a.m. 7 a.m.	91.1	30.6	+ 0.9	122.6
	Total	1398.8	388.7	+ 9.3	1796.8

[1] See pp. 42-49. [2] Not corrected for changes in body temperature and weight.

TABLE 131.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(a) Heat measured in terms of C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.	(d) Total heat production (a+b+c).
1905.		Calories	Calories	Calories	Calories
Mar. 7–8	7 a.m. to 9 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 a.m. 11 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 a.m. 1 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 p.m. 3 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 p.m. 5 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 p.m. 7 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	7 p.m. 9 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 p.m. 11 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 p.m. 1 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 a.m. 3 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 a.m. 5 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 a.m. 7 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	Total	[illegible]	[illegible]	[illegible]	[illegible]
Mar. 8–9	7 a.m. to 9 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 a.m. 11 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 a.m. 1 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 p.m. 3 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 p.m. 5 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 p.m. 7 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	7 p.m. 9 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 p.m. 11 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 p.m. 1 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 a.m. 3 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 a.m. 5 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 a.m. 7 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	Total	[illegible]	[illegible]	[illegible]	[illegible]
Mar. 9–10	7 a.m. to 9 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 a.m. 11 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 a.m. 1 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 p.m. 3 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 p.m. 5 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 p.m. 7 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	7 p.m. 9 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	9 p.m. 11 p.m.	[illegible]	[illegible]	[illegible]	[illegible]
	11 p.m. 1 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	1 a.m. 3 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	3 a.m. 5 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	5 a.m. 7 a.m.	[illegible]	[illegible]	[illegible]	[illegible]
	Total	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

TABLE 131.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 10–11..........	7 a.m. to 9 a.m......	156.6	33.1	−12.3	177.4
	9 a.m. 11 a.m	116.7	26.6	+14.8	158.1
	11 a.m. 1 p.m......	107.1	27.9	− 6.4	128.6
	1 p.m. 3 p.m......	105.8	28.5	+ 7.2	141.5
	3 p.m. 5 p.m......	114.4	26.6	− 7.0	134.0
	5 p.m. 7 p.m......	112.0	26.0	+12.7	150.7
	7 p.m. 9 p.m......	108.0	22.9	− 6.4	124.5
	9 p.m. 11 p.m......	111.9	27.2	−20.0	119.1
	11 p.m. 1 a.m......	53.1	27.3	+15.8	96.2
	1 a.m. 3 a.m......	70.2	25.6	+ 1.2	97.0
	3 a.m. 5 a.m......	76.7	28.3	+17.3	122.3
	5 a.m. 7 a.m......	82.5	26.7	+ 9.1	118.3
	Total............	1215.0	326.7	+26.0	1567.7

[1] See pp. 42-49.

BALANCE OF ENERGY.

Comparing the heat production with the total energy of the material oxidized in the body, corrected for the potential energy of the urine, gives the energy balance which is shown in table 132. The agreement between the heat production and the computed energy is on the whole very close, especially when the small quantities of heat measured are taken into consideration. The variations are, it is true, from +31 calories to —41 calories, but the average of the 7 days shows the computed heat production to be but 6 calories less than the measured, a discrepancy of —0.4 per cent.

TABLE 132.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 75.*

Date.	Energy derived from different sources. From body protein. (a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a−b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e)	(g) Total heat production.	Energy from body material greater (+) or less (—) than output. (h) Amount (f−g).	(i) Proportion (h÷g).
1905.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Mar. 4–5.....	415	97	318	1206	272	1796	1765	+31	+1.8
Mar. 5–6.....	422	136	286	1407	97	1790	1768	+22	+1.2
Mar. 6–7.....	441	138	303	1459	23	1785	1797	−12	−0.7
Mar. 7–8.....	394	146	248	1381	105	1734	1775	−41	−2.3
Mar. 8–9.....	368	147	221	1381	34	1636	1649	−13	−0.8
Mar. 9–10....	364	146	218	1238	91	1547	1553	− 6	−0.4
Mar. 10–11....	343	139	204	1264	78	1546	1568	−22	−1.4
Total, 7 days.	2747	949	1798	9336	700	11834	11875	−41	....
Av. per day..	392	135	257	1334	100	1691	1697	− 6	−0.4

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The same constancy in the various relations which the carbon dioxide elimination, oxygen consumption, and heat production bear toward each other in earlier experiments is found here. The thermal quotients for the different periods are comparatively regular throughout the experiment. This may indicate continued improvement in the experimental technique. Occasional anomalies are found both in the thermal quotients and in the respiratory quotient for the periods, but these serve only to illustrate the limitations of this type of apparatus and the difficulties encountered in securing satisfactory quotients for short periods. For 24-hour periods we believe the quotients to be accurate in all cases. The respiratory quotients were highest on the first and second days, but decreased on the third and remained practically constant for the remainder of the experiment. The respiratory quotient, as in all previous experiments without food, was highest on the first day.

TABLE 133.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 75.*

Date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b + a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d + a).	(f) Volume of carbon dioxide eliminated (d × 0.5091).	(g) Volume of oxygen consumed (b × 0.7).	(h) Respiratory quotient (f + g).
		Cals.	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1905. Mar. 4....	Preliminary: 1 a.m. to 3 a.m.	[1]135.7	35.7	26.3	39.4	29.0	20.1	25.0	0.80
	3 a.m. 5 a.m.	[1]129.4	34.4	26.6	44.2	34.2	22.5	24.1	.93
	5 a.m. 7 a.m.	[1]108.8	35.1	32.3	46.4	42.6	23.6	24.6	.96
	Total......	[1]373.9	105.2	28.1	130.0	34.8	66.2	73.7	0.90
Mar. 4-5 ..	7 a.m. to 9 a.m.	190.3	54.6	28.7	62.7	32.9	31.9	38.3	0.83
	9 a.m. 11 a.m.	176.1	44.2	25.1	56.0	31.8	28.5	30.9	.92
	11 a.m. 1 p.m.	165.9	45.5	27.4	50.1	30.2	25.5	31.9	.80
	1 p.m. 3 p.m.	138.1	39.9	28.9	46.8	33.9	23.9	27.9	.86
	3 p.m. 5 p.m.	148.0	66.9	45.2	45.0	30.4	22.9	46.8	.49
	5 p.m. 7 p.m.	149.4	42.7	28.6	49.3	33.0	25.1	29.9	.84
	7 p.m. 9 p.m.	149.4	45.8	30.7	47.0	31.5	23.9	32.1	.75
	9 p.m. 11 p.m.	150.8	47.8	31.7	50.2	33.3	25.6	33.4	.77
	11 p.m. 1 a.m.	97.1	30.6	31.5	39.5	40.7	20.1	21.4	.94
	1 a.m. 3 a.m.	110.7	34.7	31.4	38.2	34.5	19.5	24.3	.80
	3 a.m. 5 a.m.	152.5	39.8	26.1	42.5	27.9	21.6	27.8	.78
	5 a.m. 7 a.m.	136.6	41.1	30.1	42.6	31.2	21.7	28.8	.75
	Total......	1764.9	533.6	30.2	569.9	32.3	290.2	373.5	0.78

[1] See Table 131.

TABLE 133.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d × 0.5091).	(g) Volume of oxygen consumed (b × 0.7).	(h) Respiratory quotient (f ÷ g).
1905.		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Mar. 5–6 ..	7 a.m. to 9 a.m.	194.9	67.7	34.7	59.2	30.4	30.2	47.4	0.64
	9 a.m. 11 a.m.	182.4	41.3	22.6	52.3	28.7	26.7	28.9	.92
	11 a.m. 1 p.m.	159.5	44.3	27.7	48.8	30.6	24.8	31.0	.80
	1 p.m. 3 p.m.	152.8	46.6	30.5	46.4	30.4	23.6	32.6	.72
	3 p.m. 5 p.m.	140.0	39.9	28.5	44.4	31.7	22.6	27.9	.81
	5 p.m. 7 p.m.	164.3	44.6	27.1	48.3	29.4	24.6	31.2	.79
	7 p.m. 9 p.m.	141.2	42.1	29.8	46.4	32.8	23.6	29.5	.80
	9 p.m. 11 p.m.	136.6	48.4	35.5	47.6	34.9	24.2	33.9	.72
	11 p.m. 1 a.m.	115.8	29.7	25.7	37.4	32.3	19.0	20.8	.91
	1 a.m. 3 a.m.	134.5	40.0	29.8	37.9	28.2	19.3	28.0	.69
	3 a.m. 5 a.m.	113.4	52.7	46.5	39.4	34.8	20.1	36.9	.55
	5 a.m. 7 a.m.	132.7	37.0	27.9	42.5	32.0	21.6	25.9	.83
	Total......	1768.1	534.3	30.2	550.6	31.1	280.3	374.0	0.75
Mar. 6–7 ..	7 a.m. to 9 a.m.	188.0	59.9	31.8	55.2	29.3	28.1	41.9	0.67
	9 a.m. 11 a.m.	187.8	51.5	27.4	54.8	29.2	27.9	36.1	.77
	11 a.m. 1 p.m.	147.4	43.4	29.5	48.6	33.0	24.7	30.4	.81
	1 p.m. 3 p.m.	177.1	48.7	27.5	50.2	28.3	25.6	34.1	.75
	3 p.m. 5 p.m.	167.9	50.6	30.1	49.6	29.6	25.3	35.4	.71
	5 p.m. 7 p.m.	166.8	49.6	29.7	48.6	29.2	24.8	34.7	.71
	7 p.m. 9 p.m.	149.0	44.7	30.0	46.3	31.1	23.6	31.3	.75
	9 p.m. 11 p.m.	138.3	43.2	31.3	45.3	32.7	23.0	30.3	.76
	11 p.m. 1 a.m.	89.8	29.3	32.6	34.0	37.9	17.3	20.5	.84
	1 a.m. 3 a.m.	124.1	34.4	27.7	35.6	28.7	18.1	24.1	.75
	3 a.m. 5 a.m.	138.1	39.9	28.9	38.5	27.9	19.6	27.9	.70
	5 a.m. 7 a.m.	122.6	40.5	33.1	38.4	31.3	19.5	28.3	.69
	Total......	1796.9	535.7	29.8	545.1	30.3	277.5	375.0	0.74
Mar. 7–8 ..	7 a.m. to 9 a.m.	185.1	53.3	28.8	51.8	28.0	26.4	37.3	0.71
	9 a.m. 11 a.m.	162.8	46.3	28.4	49.9	30.7	25.4	32.4	.79
	11 a.m. 1 p.m.	171.5	49.5	28.8	51.9	30.3	26.5	34.6	.76
	1 p.m. 3 p.m.	162.3	50.5	31.1	49.3	30.4	25.1	35.3	.71
	3 p.m. 5 p.m.	152.6	45.4	29.8	46.4	30.4	23.6	31.8	.74
	5 p.m. 7 p.m.	169.0	51.8	30.7	54.0	32.0	27.5	36.3	.76
	7 p.m. 9 p.m.	142.2	36.1	25.4	44.1	31.0	22.4	25.3	.89
	9 p.m. 11 p.m.	138.4	50.7	36.6	43.8	31.7	22.3	35.5	.63
	11 p.m. 1 a.m.	110.7	33.5	30.2	36.8	33.3	18.8	23.4	.80
	1 a.m. 3 a.m.	110.4	30.9	28.0	31.6	28.7	16.1	21.7	.74
	3 a.m. 5 a.m.	141.4	38.5	27.2	36.0	25.4	18.3	26.9	.68
	5 a.m. 7 a.m.	129.0	33.1	25.7	38.6	29.9	19.6	23.2	.85
	Total.......	1775.4	519.6	29.3	534.2	30.1	272.0	363.7	0.75

TABLE 133.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Date.	Period.	(*a*) Total heat production.	(*b*) Oxygen consumed.	(*c*) Oxygen thermal quotient (100*b* ÷ *a*).	(*d*) Carbon dioxide eliminated.	(*e*) Carbon dioxide thermal quotient (100*d* ÷ *a*).	(*f*) Volume of carbon dioxide eliminated (*d*× 0.5091).	(*g*) Volume of oxygen consumed (*b*×0.7).	(*h*) Respiratory quotient (*f*÷*g*).
1905.		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Mar. 8–9 ..	7 a.m. to 9 a.m.	162.4	55.1	33.9	52.8	32.5	26.9	38.6	0.70
	9 a.m. 11 a.m.	159.1	38.5	24.2	43.7	27.4	22.2	26.9	.83
	11 a.m. 1 p.m.	156.2	49.6	31.8	46.8	30.0	23.8	34.7	.69
	1 p.m. 3 p.m.	152.2	43.2	28.4	45.9	30.1	23.4	30.3	.77
	3 p.m. 5 p.m.	145.8	44.7	30.6	45.1	30.9	22.9	31.3	.73
	5 p.m. 7 p.m.	155.3	39.9	25.7	44.5	28.6	22.6	28.0	.81
	7 p.m. 9 p.m.	135.3	39.0	28.8	39.8	29.5	20.3	27.3	.74
	9 p.m. 11 p.m.	126.2	44.3	35.1	41.5	32.9	21.1	31.0	.68
	11 p.m. 1 a.m.	100.0	28.6	28.6	34.4	34.4	17.5	20.0	.88
	1 a.m. 3 a.m.	104.0	31.8	30.6	32.1	30.9	16.4	22.2	.74
	3 a.m. 5 a.m.	134.6	36.3	27.0	33.3	24.8	17.0	25.4	.67
	5 a.m. 7 a.m.	117.9	40.0	33.9	36.5	31.0	18.6	28.0	.66
	Total.......	1649.0	491.0	29.8	496.4	30.1	252.7	343.7	0.74
Mar. 9–10.	7 a.m. to 9 a.m.	161.1	45.9	28.5	49.9	31.0	25.4	32.1	0.79
	9 a.m. 11 a.m.	162.7	46.8	28.8	45.4	27.9	23.1	32.8	.71
	11 a.m. 1 p.m.	140.4	42.3	30.1	41.8	29.8	21.3	29.6	.72
	1 p.m. 3 p.m.	137.4	38.0	27.7	41.3	30.0	21.0	26.6	.79
	3 p.m. 5 p.m.	121.7	35.5	29.2	37.1	30.5	18.9	24.9	.76
	5 p.m. 7 p.m.	150.8	45.4	30.1	41.7	27.6	21.2	31.8	.67
	7 p.m. 9 p.m.	120.0	38.9	32.4	40.5	33.8	20.6	27.2	.76
	9 p.m. 11 p.m.	120.9	42.0	34.8	44.5	36.8	22.6	29.4	.77
	11 p.m. 1 a.m.	104.3	34.1	32.7	33.2	31.9	16.9	23.9	.71
	1 a.m. 3 a.m.	85.0	28.0	33.0	32.0	37.7	16.3	19.6	.83
	3 a.m. 5 a.m.	122.6	33.3	27.2	33.9	27.7	17.3	23.3	.74
	5 a.m. 7 a.m.	125.9	35.9	28.5	36.1	28.7	18.4	25.1	.73
	Total.......	1552.8	466.1	30.0	477.4	30.7	243.0	326.3	0.75
Mar. 10–11.	7 a.m. to 9 a.m.	177.4	50.3	28.4	48.7	27.5	24.8	35.2	0.70
	9 a.m. 11 a.m.	158.1	44.6	28.2	42.5	26.9	21.6	31.2	.69
	11 a.m. 1 p.m.	128.6	35.3	27.4	39.6	30.8	20.2	24.7	.82
	1 p.m. 3 p.m.	141.5	42.3	29.9	44.8	31.6	22.8	29.6	.77
	3 p.m. 5 p.m.	134.0	39.2	29.2	41.1	30.7	20.9	27.4	.76
	5 p.m. 7 p.m.	150.7	45.1	29.9	44.5	29.5	22.7	31.6	.72
	7 p.m. 9 p.m.	124.5	40.0	32.2	43.2	34.7	22.0	28.0	.79
	9 p.m. 11 p.m.	119.1	39.3	33.0	37.9	31.8	19.3	27.5	.70
	11 p.m. 1 a.m.	96.2	30.5	31.7	32.2	33.5	16.4	21.4	.77
	1 a.m. 3 a.m.	97.0	30.6	31.6	30.4	31.3	15.4	21.4	.72
	3 a.m. 5 a.m.	122.3	33.0	26.9	33.9	27.7	17.3	23.1	.75
	5 a.m. 7 a.m.	118.3	36.2	30.6	36.8	31.1	18.7	25.4	.74
	Total......	1567.7	466.4	29.8	475.6	30.3	242.1	326.5	0.74

METABOLISM EXPERIMENT NO. 76.

This experiment, which lasted 3 days, followed metabolism experiment No. 75. The statistical data given in the following tables show both the actual katabolism during this experiment and the relation of the food to the total metabolism.

Notes from diary, pulse records, and records of body movements.—The notes made by the subject concerning his physical and mental condition are given below. In addition a few observations are recorded which were obtained during the time of the experiment by questioning the subject. Following these observations the records of pulse and body movements are given.

Notes from diary.

March 11, 1905:

7h30m a. m. Slept better than during previous night, but was in pain again. Tongue still swollen and coated; gums and teeth are very painful.

7h35m a. m. Drank first portion of orange juice.

9h45m a. m. Ate my first portion of food.

12h30m p. m. Finished second portion of food.

7h35m p. m. Finished my last portion of food. Milk seems to be too sweet and portions of food were given too close together. Should be from 3½ to 4 hours apart.

9h15m p. m. Made an unsuccessful attempt to defecate.

9h30m p. m. Commenced to wear rectal thermometer. Feels comfortable.

10 p. m. Passed a fairly comfortable day but not as good as yesterday. Tongue swelling is gradually diminishing but gums and teeth are still sore.

March 12, 1905:

7h20m a. m. Passed a fairly comfortable night. Tongue is still swollen and coated; bitter taste in mouth. Eyes clear and bright; do not feel weak or nervous.

8h30m a. m. Drank first portion of orange juice.

9h45m a. m. Finished my first allotment of food; tasted good.

10 a. m. Have been very quiet.

1h15m p. m. Drank second portion of orange juice.

2h30m p. m. Finished second portion of food.

7h35m p. m. Finished third portion of food.

9 p. m. Finished third portion of orange juice.

10 p. m. Passed the day surprisingly well. Tongue still swollen and end feels raw; teeth and gums better.

March 13, 1905:

7h20m a. m. Good sleep. Tongue swollen and coated; eyes clear and bright. Nostrils feel dry and sore.

8h10m a. m. Defecated with difficulty. Feel very much better. Rectum feels very sore and painful.

9h35m a. m. Finished first portion of food.

1h30m p. m. Drank second portion of orange juice. Tastes a little bitter.

2h30m p. m. Finished second portion of food.

6h50m p. m. Nose bled. Air in chamber feels irritating to nostrils.

8 p. m. Finished third portion of food.

8h20m p. m. Drank third portion of orange juice.

10 p. m. Passed a fairly good day.

Observations reported by telephone.

March 11, 1905:

4h20m p. m. Feel well; sleepy; not hungry. Meals come too close together; tongue slightly better. Food agrees with me.

7h10m p. m. Feeling well; tongue improving; not sleepy; meals too close together. Prefer them farther apart and with more food at a time.

March 12, 1905:

8h10m a. m. Feeling well; tongue improving; did not sleep very well; feel hungry.

March 13, 1905:

11h20m a. m. Feel fairly well; tongue still swollen but is improving. Feel weak after movement of bowels which required nearly half an hour.

Pulse rate experiment No. 76.[1]

Time.	Pulse rate.	Time.	Pulse rate.	Time.	Pulse rate.
Mar. 11 7h 30m a.m..	67	Mar. 12 7h 30m a.m..	68	Mar 13 7h 30m a.m..	77
8 00 a.m..	67	8 00 a.m..	68	8 15 a.m..	78
10 00 a.m..	77	10 00 a.m..	[2]91	10 00 a.m..	87
12 00 a.m..	75	12 00 a.m..	69	12 00 p.m..	86
2 00 p.m..	80	2 00 p.m..	69	2 00 p.m..	78
4 00 p.m..	81	4 00 p.m..	72	4 00 p.m..	81
6 00 p m..	64	6 00 p.m..	76	6 00 p.m..	76
8 00 p.m..	75	8 00 p.m..	77	8 00 p.m..	72
10 00 p.m..	70	10 00 p.m..	76	10 00 p.m..	70

[1] Pulse taken while sitting. [2] Very fast and strong.

Movements of subject, duration 3 days, from Mar. 11, 7 a. m., to Mar. 14, 7 a. m., 1905.

March 11.

A.M.
7h 00m rise, open curtain.
7 02 urinate, move chair.
7 04 } fold bed, dress,
7 09 } weigh self, etc.
7 11 food aperture.
7 15 food aperture, drink.
7 18 comb hair, telephone.
7 25 drink.
7 30 count pulse.
7 35 drink.
7 38 rise, food aperture, sit.
7 44 read.
8 00 count pulse.
8 20 food aperture.
8 22 read, drink.
8 29 food aperture, read.
9 02 move about, sit.
9 08 food aperture.
9 12 food aperture.
9 20 eat, read.
9 44 stand, blood sampled.
9 54 sit, read.
9 55 rinse bottle.
10 00 count pulse.
10 04 food aperture.
10 06 read.
11 08 food aperture.
11 10 move about.
11 16 eat, read.
12 00 count pulse.

P. M.
12h 02m food aperture, sit.
12 30 finish eating, food aperture.
12 55 drink.
1 02 move about, food aperture.
1h 06m urinate.
1 08 sit.
1 23 food aperture.
1 36 food aperture.
1 38 eat.
1 42 read.
2 00 count pulse.
2 14 food aperture.
2 16 move about.
2 18 sit.
2 32 head on table.
2 36 asleep.
3 48 awake.
3 52 drink.
3 54 write.
4 00 count pulse.
4 02 move about, urinate.
4 04 sit.
4 06 asleep.
4 14 awake.
4 32 asleep.
4 40 awake.
5 01 drink.
5 28 stand, telephone.
5 30 move about, sit.
5 32 kneel, doctor count pulse.
5 34 coat off, blood pressure test.
5 48 coat on, sit, read.
6 00 count pulse.
6 16 rise, food aperture.
6 24 rise, food aperture.
6 54 rise, food aperture, urinate.
7 02 telephone.
7 15 rise, food aperture.
7 35 finish eating, write.
7 36 food aperture.
8 00 count pulse.
8 02 rise, gymnastics.
8 12 food aperture.
8h 18m drink.
9 06 food aperture.
9 08 stand, sit, read.
9 12 rise, food aperture.
9 14 close curtain, attempt to defecate.
9 28 open curtain, move about.
9 30 adjust thermometer.
9 40 telephone.
9 50 drink.
10 00 count pulse.
10 12 rise, lower table, open bed, recline, read.
11 00 rise, urinate, undress.
11 04 close curtain.

March 12.

A. M.
7h 00m rise, open curtain.
7 02 } urinate, move
7 09 } chair, weigh self, etc.
7 12 raise table, sit.
7 15 food aperture.
7 20 comb hair.
7 25 drink.
7 30 count pulse, write.
7 47 drink.
8 00 count pulse.
8 02 read.
8 55 drink.
9 02 move about.
9 04 stand, blood sampled.
9 10 move about, urinate.
9 12 sit.
9 14 food aperture.
9 24 eat, read.

***Movements of subject.*—Continued.**

March 12 (cont).

A. M.
9h 45m finish eating, write.
9 50 drink.
10 00 count pulse.
10 04 food aperture.
10 06 sit.
10 12 read.
10 22 move about.
10 24 sit.
10 26 read.
11 00 drink.
11 08 food aperture.
11 22 move about.
11 24 food aperture.
11 26 read.
11 40 drink.
11 42 food aperture.
12 00 count pulse.

P. M.
12h 25m drink.
1 02 move about.
1 04 telephone, food aperture, urinate.
1 08 lean on table, read.
1 12 move about, food aperture.
1 14 sit.
1 15 drink.
1 42 read.
2 00 count pulse.
2 08 move about.
2 10 eat, read.
2 30 finish eating, write.
3 04 food aperture.
3 45 food aperture.
4 04 count pulse.
4 08 read.
4 26 eat.
4 28 read.
5 04 move about, urinate.
5 06 sit, read.
5 15 food aperture.
5 18 } 5 22 } stand, blood pressure test.
5 26 sit, read.
5 50 drink.
6 00 count pulse.
6 12 food aperture.
7 02 rise, food aperture.
7 16 rise, food aperture.
7 20 eat.
7 35 finish eating.
7 40 food aperture.
7 52 food aperture.
7 58 telephone.
8 00 count pulse.
8 05 food aperture.
9 00 drink.

P. M.
9h 10m drink.
10 00 count pulse.
10 05 drink.
10 12 rise, open bed, recline, read.
11 00 rise, undress, urinate, close curtain, retire.

March 13.

A. M.
7h 00m rise, open curtain.
7 02 } 7 08 } urinate, weigh self, etc.
7 14 raise table.
7 16 food aperture, sit.
7 25 drink.
7 30 count pulse.
7 32 remove thermometer.
7 36 close curtain.
7 40 defecate.
8 08 open curtain.
8 10 sit, write.
8 14 food aperture.
8 15 count pulse.
8 16 read.
8 20 food aperture.
8 30 drink.
9 04 stand, blood sampled.
9 05 drink.
9 10 sit.
9 16 food aperture.
9 18 food aperture.
9 20 sit, rest.
9 35 finish eating.
9 38 food aperture.
9 42 read.
10 00 count pulse.
10 02 food aperture.
10 05 drink.
10 28 move about.
10 38 head on table, asleep.
11 00 awake, food aperture.
11 04 move about.
11 10 sit, read.
11 12 food aperture.
11 35 drink.
12 00 count pulse.

P. M.
12h 02m move about, urinate, sit.
12 06 read.
12 25 drink.
1 00 urinate.
1 01 food aperture.

P. M.
1h 08m food aperture.
1 12 sit, drink.
1 54 move about, food aperture.
2 00 count pulse.
2 30 finish eating.
2 45 drink.
3 02 food aperture.
3 04 stand.
3 08 move about, food aperture.
3 12 sit.
3 14 read.
3 36 move around, read.
4 00 count pulse.
4 05 drink.
4 06 move about.
4 08 sit, read.
4 16 move chair.
4 20 write.
4 28 telephone.
4 38 move about.
4 40 write.
5 02 } 5 06 } move about, blood pressure test.
5 08 telephone.
5 10 sit.
5 16 count pulse.
5 20 telephone.
5 24 move about.
5 28 sit.
6 00 count pulse.
6 04 rise, move about.
6 12 sit, read.
6 16 food aperture.
6 20 wave arms.
6 22 telephone.
7 04 urinate, food aperture.
7 06 telephone.
7 20 finish eating, rise, sit.
7 50 food aperture, move about, stand.
7 56 food aperture.
7 58 telephone.
8 00 count pulse.
8 07 food aperture.
8 20 drink.
8 45 drink.
9 50 drink.
10 00 count pulse.
10 14 rise, lower table, open bed, recline, read.
11 00 rise, urinate, undress, close curtain.

WATER AND OXYGEN CONSUMED, AND URINE, CARBON DIOXIDE, AND WATER-VAPOR ELIMINATED.

The data showing the amounts of water drunk, the determinations in the urine per period and per day, the elimination of water-vapor, and the oxygen intake and output of carbon dioxide are given in tables 134 to 138. As in experiment No. 75, the water drunk during each period was measured.

TABLE 134.—*Record of water consumed—Metabolism experiment No. 76.*

Date.	7 to 9 a.m.	9 to 11 a.m.	11 a.m. to 1 p.m.	1 to 3 p.m.	3 to 5 p.m.	5 to 7 p.m.	7 to 9 p.m.	9 to 11 p.m.	Total for day.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 11–12....	220.0	75.0	93.0	144.4	144.3	150.0	50.0	144.4	1021.1
Mar. 12–13....	273.0	73.0	245.4	....	....	244.2	....	207.9	1043.5
Mar. 13–14....	105.2	130.0	155.0	70.0	193.0	170.5	148.5	98.3	1070.5

TABLE 135.—*Determinations in urine per period and per day—Metabolism experiment No. 76.*

Date and period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a+b).	(d) Reaction.	(e) Nitrogen.	(f) Phosphoric acid by titration (P_2O_5).	(g) Creatinine excreted (preformed)
1905.							
Mar. 11–12:	*Grams.*		*c. c.*		*Grams.*	*Grams.*	*Grams.*
7 a.m. to 1 p.m....	431.7	1.0114	427	Neutral......	3.45	0.375	0.268
1 p.m. 7 p.m....	921.4	1.0048	918	....do.......	3.62	.200	.302
7 p.m. 11 p.m....	183.5	1.0068	182	....do.......	1.43	.084	.189
11 p.m. 7 a.m....	199.2	1.0084	198	....do.......	1.67	.168	.360
Total.............	1735.8	....	1725	....	10.17	.822	1.114
Total by composite.	1735.8	1.0063	1725	Neutral......	10.18	.757	1.137
Mar. 12–13:							
7 a.m. to 1 p.m....	548.0	1.0024	547	Neutral......	2.11	.113	.365
1 p.m. 7 p.m....	272.0	1.0059	271	....do......	2.02	.109	.304
7 p.m. 11 p.m....	112.1	1.0085	111	....do.......	1.02	....	.194
11 p.m. 7 a.m....	381.6	1.0058	379	Slightly acid.	2.00	.157	.370
Total.............	1313.7	....	1308	....	7.15	....	1.233
Total by composite.	1313.7	1.0047	1308	Neutral......	7.17	.375	1.292
Mar. 13–14:							
7 a.m. to 1 p.m....	311.4	1.0056	310	Neutral......	1.59	.053	.348
1 p.m. 7 p.m....	400.0	1.0048	398	Slightly acid.	2.12	.137	.350
7 p.m. 11 p.m....	272.8	1.0045	272	Neutral......	1.33	.125	.217
11 p.m. 7 a.m.....	619.0	1.0050	616	Slightly acid.	2.78	.474	.431
Total.............	1603.2	....	1596	....	7.82	.789	1.346
Total by composite.	1603.2	1.0046	1596	Acid.........	7.78	.742	1.346
Total for 3 days....	4652.7	....	4629	....	25.14	....	3.693

TABLE 136.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 76.*

	Mar. 11-12.	Mar. 12-13.	Mar. 13-14.	Total for 3 days.
(*a*) Weight .... grams..	1735.8	1313.7	1603.2	4652.7
(*b*) Water .... do....	1695.18	1290.45	1576.11	4561.74
(*c*) Solids, *a*—*b* .... do....	40.62	23.25	27.09	90.96
(*d*) Ash .... do....	1.74	1.84	3.69	7.27
(*e*) Organic matter, *c*—*d* .... do...	38.88	21.41	23.40	83.69
(*f*) Nitrogen .... do....	10.17	7.15	7.82	25.14
(*g*) Carbon .... do....	11.63	5.65	5.93	23.21
(*h*) Hydrogen in organic matter ... do....	2.60	1.45	1.60	5.65
(*i*) Oxygen (by difference) in organic matter, *e*—(*f*+*g*+*h*) .... grams..	14.48	7.16	8.05	29.69
(*j*) Phosphorus .... do....	.336	.153	.351	.840
Phosphoric acid (P_2O_5):				
(*k*) By fusion .... grams..	.770	.350	.804	1.924
(*l*) By titration .... do....	.757	.375	.742	1.874
(*m*) Sulphur .... do....	.655	.546	.593	1.794
Sulphur trioxide (SO_3):				
(*n*) Total .... grams..	1.634	1.364	1.481	4.479
(*o*) Inorganic and ethereal ..... do....	1.425	1.206	1.353	3.984
(*p*) Neutral, *n*—*o* .... do....	.209	.158	.128	.495
(*q*) Creatinine (preformed) .... do....	1.137	1.292	1.346	3.775
(*r*) Total creatinine .... do....	1.411	....	....	....
(*s*) Creatine[1] (preformed), *r*—*q* .... do....	.274	....	....	....
(*t*) Chlorine .... do....	.364	.494	2.137	2.995
(*u*) Sodium chloride .... do....	.601	.815	3.526	4.942
(*v*) Heat of combustion .... calories..	125	66	69	260

[1] In terms of creatinine.

TABLE 137.—*Record of water of respiration and perspiration—Metabolism experiment No. 76.*

Date.	Period.	(*a*) Total am'nt of vapor in chamber at end of period.	(*b*) Total water of respiration and perspiration.[1]
1905.		*Grams.*	*Grams.*
	Preliminary:		
Mar. 11....	5 a.m. to 7 a.m.	20.7	....
Mar. 11–12.	7 a.m. to 9 a.m.	24.0	57.2
	9 a.m. 11 a.m.	24.7	50.1
	11 a.m. 1 p.m.	24.5	55.4
	1 p.m. 3 p.m.	24.7	55.9
	3 p.m. 5 p.m.	24.2	52.0
	5 p.m. 7 p.m.	25.4	48.6
	7 p.m. 9 p.m.	25.8	54.7
	9 p.m. 11 p.m.	24.4	53.1
	11 p.m. 1 a.m.	22.9	48.6
	1 a.m. 3 a.m.	23.4	47.5
	3 a.m. 5 a.m.	21.9	46.8
	5 a.m. 7 a.m.	21.6	46.9
	Total......	....	616.8
Mar. 12–13.	7 a.m. to 9 a.m.	24.9	51.0
	9 a.m. 11 a.m.	24.5	46.5
	11 a.m. 1 p.m.	23.4	49.6
	1 p.m. 3 p.m.	24.3	50.0
	3 p.m. 5 p.m.	24.4	50.4
	5 p.m. 7 p.m.	24.8	50.5
1905. Mar. 12–13.	7 p.m. to 9 p.m.	24.0	50.8
	9 p.m. 11 p.m.	24.0	52.5
	11 p.m. 1 a.m.	21.7	46.1
	1 a.m. 3 a.m.	22.3	46.6
	3 a.m. 5 a.m.	20.1	43.4
	5 a.m. 7 a.m.	20.7	45.0
	Total......	....	582.3
Mar. 13–14.	7 a.m. to 9 a.m.	25.7	58.7
	9 a.m. 11 a.m.	22.6	46.0
	11 a.m. 1 p.m.	23.8	58.5
	1 p.m. 3 p.m.	24.8	52.6
	3 p.m. 5 p.m.	25.1	54.6
	5 p.m. 7 p.m.	24.9	51.7
	7 p.m. 9 p.m.	24.5	56.7
	9 p.m. 11 p.m.	22.9	50.1
	11 p.m. 1 a.m.	21.6	48.1
	1 a.m. 3 a.m.	21.9	46.8
	3 a.m. 5 a.m.	21.6	47.6
	5 a.m. 7 a.m.	21.0	45.0
	Total......	....	611.4

[1] Allowance has been made for water gained or lost by the chair, bedding, and miscellaneous articles as follows: March 11-12, 1.52 grams gained; March 12-13, 14.24 grams lost; March 13-14, 0.72 gram gained.

TABLE 138.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 76.*

Date.	Period.	Carbon dioxide.		Oxygen.	
		(a) Amount in chamber at end of period.	(b) Total weight exhaled by subject.	(c) Amount in chamber at end of period.	(d) Total amount consumed by subject.
1905.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Mar. 11......	5 a. m. to 7 a. m..	16.9	....	887.8	....
Mar. 11-12...	7 a. m. to 9 a. m..	22.3	52.9	917.8	55.6
	9 a. m. 11 a. m..	25.6	51.9	916.6	50.7
	11 a. m. 1 p. m..	26.8	53.7	917.8	46.3
	1 p. m. 3 p. m..	23.9	54.3	913.0	60.0
	3 p. m. 5 p. m..	25.5	46.5	916.7	42.9
	5 p. m. 7 p. m..	24.4	46.4	919.5	42.8
	7 p. m. 9 p. m..	29.7	50.1	918.2	49.1
	9 p. m. 11 p. m..	24.0	52.4	920.5	48.6
	11 p. m. 1 a. m..	23.5	37.5	926.3	32.3
	1 a. m. 3 a. m..	17.8	32.8	927.6	34.4
	3 a. m. 5 a. m..	23.0	36.2	923.9	33.2
	5 a. m. 7 a. m..	18.5	36.7	922.4	31.3
	Total...........	....	551.4	....	527.2
Mar. 12-13...	7 a. m. to 9 a. m..	32.3	50.8	908.7	54.5
	9 a. m. 11 a. m..	27.4	51.5	900.6	44.6
	11 a. m. 1 p. m..	35.8	51.5	891.0	44.4
	1 p. m. 3 p. m..	29.3	53.9	888.0	51.9
	3 p. m. 5 p. m..	38.8	52.8	877.4	44.0
	5 p. m. 7 p. m..	27.7	51.0	886.7	47.3
	7 p. m. 9 p. m..	37.5	52.1	882.5	46.2
	9 p. m. 11 p. m..	27.1	53.4	895.7	43.1
	11 p. m. 1 a. m..	18.6	37.3	906.0	31.1
	1 a. m. 3 a. m..	17.7	34.2	902.9	31.4
	3 a. m. 5 a. m..	18.1	34.5	912.5	29.8
	5 a. m. 7 a. m..	17.9	37.4	910.5	31.9
	Total...........	....	560.4	....	500.2
Mar. 13-14...	7 a. m. to 9 a. m..	27.8	67.8	903.6	60.7
	9 a. m. 11 a. m..	26.6	55.6	909.8	46.8
	11 a. m. 1 p. m..	24.4	53.3	900.5	44.5
	1 p. m. 3 p. m..	24.8	53.5	889.8	45.7
	3 p. m. 5 p. m..	29.0	60.3	884.9	48.6
	5 p. m. 7 p. m..	26.1	54.6	888.9	48.9
	7 p. m. 9 p. m..	28.2	58.9	892.2	49.3
	9 p. m. 11 p. m..	23.6	49.8	896.8	42.2
	11 p. m. 1 a. m..	19.3	37.7	898.5	26.9
	1 a. m. 3 a. m..	17.6	36.5	896.9	31.1
	3 a. m. 5 a. m..	20.4	40.2	896.0	31.8
	5 a. m. 7 a. m..	18.4	40.2	898.3	30.6
	Total...........	....	608.4	....	507.1

ELEMENTS AND MATERIALS KATABOLIZED IN BODY.

The data in tables 139 and 140 correspond in all respects to the similar tables for previous food experiments. Food and water ingested have not been considered in obtaining the results.

TABLE 139.—*Elements katabolized in body—Metabolism experiment No. 76.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Mar. 11, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	527.25	....	....	....	527.25	....
Outgo:						
Water in urine.............	1695.18	....	....	189.69	1505.49	....
Solids in urine.............	40.62	10.17	11.63	2.60	14.48	1.74
Water of respiration [1].......	616.81	....	....	69.02	547.79	....
Carbon dioxide.............	551.36	....	150.38	....	400.98	....
Total....................	2903.97	10.17	162.01	261.31	2468.74	1.74
Loss....................	2376.72	10.17	162.01	261.31	1941.49	1.74
Second day, Mar. 12, 1905.						
Income: Oxygen from air......	500.16	....	....	....	500.16	....
Outgo:						
Water in urine.............	1290.45	....	....	144.40	1146.05	....
Solids in urine.............	23.25	7.15	5.65	1.45	7.16	1.84
Water of respiration [1].......	582.30	....	....	65.16	517.14	....
Carbon dioxide.............	560.44	....	152.83	....	407.61	....
Total....................	2456.44	7.15	158.48	211.01	2077.96	1.84
Loss....................	1956.28	7.15	158.48	211.01	1577.80	1.84
Third day, Mar. 13, 1905.						
Income: Oxygen from air.......	507.08	....	....	....	507.08	....
Outgo:						
Water in urine.............	1576.11	....	....	176.37	1399.74	....
Solids in urine.............	27.09	7.82	5.93	1.60	8.05	3.69
Water of respiration [1].......	611.39	....	....	68.41	542.98	....
Carbon dioxide.............	608.39	....	165.93	....	442.46	....
Total....................	2822.98	7.82	171.86	246.38	2393.23	3.69
Loss....................	2315.90	7.82	171.86	246.38	1886.15	3.69

[1] Includes also water of perspiration.

TABLE 140.—*Elements and materials katabolized in body—Metabolism experiment No. 76.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 11–12 ...	10.17	162.01	261.31	1941.49	2120.57	61.02	137.95	56.37	1.74
Mar. 12–13....	7.15	158.48	211.01	1577.80	1678.66	42.90	101.92	131.62	1.84
Mar. 13–14....	7.82	171.86	246.38	1886.15	1981.87	46.92	66.67	217.47	3.69
Total, 3 days.	25.14	492.35	718.70	5405.44	5781.10	150.84	306.54	405.46	7.27

TOTAL HEAT PRODUCTION, MEASURED AND COMPUTED.

The total heat production for each 2-hour period of the experiment is shown in table 141, together with the summarized data from which it is obtained.

TABLE 141.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 76.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Mar. 11–12..........	7 a.m. to 9 a.m......	152.8	33.8	+ 2.0	188.6
	9 a.m. 11 a.m......	117.6	29.6	+17.1	164.3
	11 a.m. 1 p.m......	119.4	32.8	− 2.7	149.5
	1 p.m. 3 p.m......	135.7	33.0	+18.7	187.4
	3 p.m. 5 p.m......	129.8	30.7	− 6.7	153.8
	5 p.m. 7 p.m......	130.0	28.6	− 6.5	152.1
	7 p.m. 9 p.m......	121.0	32.3	+ 3.6	156.9
	9 p.m. 11 p.m......	125.4	31.4	− 0.5	156.3
	11 p.m. 1 a.m......	71.8	28.7	+10.4	110.9
	1 a.m. 3 a.m......	88.6	28.1	+ 5.2	121.9
	3 a.m. 5 a.m......	86.9	27.6	+ 2.4	116.9
	5 a.m. 7 a.m	77.0	27.6	+ 3.8	108.4
	Total..............	1356.0	364.2	+46.8	1767.0
Mar. 12–13..........	7 a.m. to 9 a.m......	155.1	30.9	+ 5.3	191.3
	9 a.m. 11 a.m	126.6	28.2	+ 5.8	160.6
	11 a.m. 1 p.m	113.3	30.1	+21.1	164.5
	1 p.m. 3 p.m......	135.3	30.3	+21.9	187.5
	3 p.m. 5 p.m......	130.3	30.5	− 3.6	157.2
	5 p.m. 7 p.m......	126.9	30.6	− 1.7	155.8
	7 p.m. 9 p.m......	125.2	30.8	+ 9.7	165.7
	9 p.m. 11 p.m......	126.6	31.8	−17.7	140.7
	11 p.m. 1 a.m......	57.2	28.0	− 7.8	77.4
	1 a.m. 3 a.m......	66.9	28.2	+12.1	107.2
	3 a.m. 5 a.m......	83.0	26.4	+ 2.9	112.3
	5 a.m. 7 a.m......	75.9	27.4	+ 4.9	108.2
	Total..............	1322.3	353.2	+52.9	1728.4
Mar. 13–14..........	7 a.m. to 9 a.m......	164.9	34.7	− 8.9	190.7
	9 a.m. 11 a.m......	134.0	27.2	+12.4	173.6
	11 a.m. 1 p.m......	119.7	31.6	+ 4.8	156.1
	1 p.m. 3 p.m......	108.9	31.1	+28.8	168.8
	3 p.m. 5 p.m	133.3	32.3	− 6.2	159.4
	5 p.m. 7 p.m......	130.5	30.6	+ 0.7	161.8
	7 p.m. 9 p.m......	118.8	33.5	+15.6	167.9
	9 p.m. 11 p.m......	132.5	29.7	−14.6	147.6
	11 p.m. 1 a.m......	55.6	28.4	+ 4.8	88.8
	1 a.m. 3 a.m......	83.1	27.6	+ 7.4	118.1
	3 a.m. 5 a.m......	82.9	28.2	+ 1.5	112.6
	5 a.m. 7 a.m......	77.7	26.6	+ 3.8	108.1
	Total..............	1341.9	361.5	+50.1	1753.5

[1] See pages 42-49.

In table 142, the computed energy of the body material katabolized is compared with the daily heat produced (column *d*, table 141).

TABLE 142.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 76.*

Date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater (+) or less (−) than output.	
	From body protein.			(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).		(h) Amount (f−g).	(i) Proportion (h÷g).
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a—b).						
1906.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Mar. 11–12....	345	125	220	1316	236	1772	1767	+ 5	+0.3
Mar. 12–13....	242	66	176	972	551	1699	1728	−29	−1.7
Mar. 13–14....	265	69	196	636	911	1743	1753	−10	−0.6
Total, 3 days.	852	260	592	2924	1698	5214	5248	−34	....
Av. per day..	284	87	197	975	566	1738	1749	−11	−0.6

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

In table 143 are recorded the oxygen and carbon dioxide thermal quotients and the respiratory quotients per period and per day.

EFFECT OF INGESTION OF FOOD.

Diet.—The food consisted of milk, gluten crackers, apple, orange juice, and a small quantity of a breakfast food which was added to the diet at the request of the subject. The results of the analyses of the different food materials and of the feces for the experimental period are given in table 144. The amounts of food eaten and the composition and heat of combustion are shown in table 145, together with the weight and composition of the feces. Feces were not passed until the morning of March 13 (total weight, 28.1 grams). The last previous defecation was at 9^h 10^m a. m., March 4.

Elements and materials absorbed from food.—The usual custom of assigning to each day one-third of the feces separated for the experiment was here followed, and since the daily intake of food was constant it is assumed that there was a constancy in the elements absorbed from the food when computed according to the usual method of deducting the elements of the feces from the elements of the food. The quantities of water consumed, however, varied from day to day, and hence the remarks made in the discussion of experiment No. 74 regarding the computation of the quantities of material absorbed from the food apply also here. The data in terms of elements for the first day of the experiment are shown in table 146. The average daily amounts of materials absorbed, as computed by the formulæ, are as follows: Protein,

30.18 grams; fat, 76.78 grams; and carbohydrates, 190.01 grams. As already explained, slight variations from these amounts occur on the different days of the experiment. These appear in lines *d* and *g* of table 150.

TABLE 143.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 76.*

Date and period.	(*a*) Total heat production.	(*b*) Oxygen consumed.	(*c*) Oxygen thermal quotient (100*b*÷*a*).	(*d*) Carbon dioxide eliminated.	(*e*) Carbon dioxide thermal quotient (100*d*÷*a*).	(*f*) Volume of carbon dioxide eliminated (*d*×0.5091)	(*g*) Volume of oxygen consumed (*b*×0.7).	(*h*) Respiratory quotient (*f*÷*g*).
1905. Mar. 11–12:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
7 a.m. to 9 a.m.	188.6	55.6	29.5	52.9	28.1	27.0	38.9	0.69
9 a.m. 11 a.m.	164.3	50.7	30.9	51.9	31.6	26.4	35.5	.74
11 a.m. 1 p.m.	149.5	46.3	31.0	53.7	35.9	27.3	32.4	.84
1 p.m. 3 p.m.	187.4	60.1	32.1	54.3	28.9	27.6	42.1	.66
3 p.m. 5 p.m.	153.8	42.9	27.9	46.5	30.2	23.7	30.0	.79
5 p.m. 7 p.m.	152.1	42.8	28.1	46.4	30.5	23.6	30.0	.79
7 p.m. 9 p.m.	156.9	49.1	31.3	50.1	31.9	25.5	34.4	.74
9 p.m. 11 p.m.	156.3	48.6	31.1	52.4	33.5	26.7	34.0	.78
11 p.m. 1 a.m.	110.9	32.3	29.2	37.5	33.8	19.1	22.7	.84
1 a.m. 3 a.m.	121.9	34.4	28.2	32 8	26.9	16.7	24.0	.69
3 a.m. 5 a.m.	116.9	33.2	28.4	36.2	31.0	18.4	23.2	.79
5 a.m. 7 a.m.	108.4	31.3	28.8	36.7	33.9	18.7	21.9	.86
Total.........	1767.0	527.3	29.8	551.4	31.2	280.7	369.1	0.76
Mar. 12–13:								
7 a.m. to 9 a.m.	191.3	54.5	28.5	50.8	26.6	25.9	38.1	0.68
9 a.m. 11 a.m.	160.6	44.6	27.8	51.5	32.1	26.2	31.2	.84
11 a.m. 1 p.m.	164.5	44.4	27.0	51.5	31.3	26.2	31.1	.84
1 p.m. 3 p.m.	187.5	51.9	27.7	53.9	28.8	27.4	36.3	.76
3 p.m. 5 p.m.	157.1	44.0	28.0	52.8	33.6	26.9	30.8	.87
5 p.m. 7 p.m.	155.8	47.3	30.4	51.0	32.8	26.0	33.1	.78
7 p.m. 9 p.m.	165.7	46.2	27.9	52.1	31.5	26.5	32.3	.82
9 p.m. 11 p.m.	140.7	43.1	30.6	53.4	37.9	27.2	30.2	.90
11 p.m. 1 a.m.	77.4	31.1	40.2	37.3	48.1	19.0	21.8	.87
1 a.m. 3 a.m.	107.3	31.4	29.2	34.2	31.8	17.4	22.0	.79
3 a.m. 5 a.m.	112.3	29.8	26.5	34.5	30.7	17.6	20.9	.84
5 a.m. 7 a.m.	108.2	31.9	29.4	37.5	34.6	19.0	22.3	.86
Total.........	1728 4	500.2	28.9	560.5	32.4	285.3	350.1	0.82
Mar. 13–14:								
7 a.m. to 9 a.m.	190.7	60.7	31.8	67.8	35.5	34.5	42.5	0.81
9 a.m. 11 a.m.	173.6	46.8	27.0	55.6	32.0	28.3	32.8	.86
11 a.m. 1 p.m.	156.1	44.5	28.5	53.3	34.1	27.1	31.2	.87
1 p.m. 3 p.m.	168.8	45.7	27.1	53.5	31.7	27.2	32.0	.85
3 p.m. 5 p.m.	159.4	48.6	30.5	60.3	37.8	30.7	34.0	.90
5 p.m. 7 p.m.	161.8	48.9	30.2	54.6	33.8	27.8	34.2	.81
7 p.m. 9 p.m.	167.9	49.3	29.3	58.9	35.1	30.0	34.5	.87
9 p.m. 11 p.m.	147.6	42.2	28.6	49.8	33.8	25.4	29.5	.86
11 p.m. 1 a.m.	88.8	26.9	30.3	37.7	42.5	19.2	18.9	1.02
1 a.m. 3 a.m.	118.2	31.1	26.3	36.5	30.9	18.6	21.8	.85
3 a.m. 5 a.m.	112.5	31.8	28.2	40.2	35.7	20.5	22.2	.92
5 a.m. 7 a.m.	108.1	30 6	28.3	40.2	37.2	20.5	21.4	.96
Total.........	1753.5	507.1	28.9	608.4	34.7	309.8	355.0	0.87

TABLE 144.—*Percentage composition of food and feces—Metabolism experiment No. 76.*

Laboratory number.	Kind of material.	(a) Water.	(b) Protein.	(c) Fat.	(d) Carbohydrates.	(e) Ash.	(f) Nitrogen.	(g) Carbon.	(h) Hydrogen.	(i) Heat of combustion per gram.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cals.*
3841	Milk	81.07	1.09	10.39	7.22	0.23	0.17	11.18	1.79	1.296
3842	Apple	86.68	1.97	....	11.06	0.29	0.35	5.56	0.85	0.526
3843	Orange juice	87.40	0.59	....	11.60	0.41	0.10	4.39	0.78	0.478
3844	Shredded wheat	7.22	10.12	1.75	79.11	1.80	1.78	42.25	6.80	4.098
3845	Gluten crackers	3.21	81.51	0.83	12.61	2.34	14.30	49.93	7.30	5.447
3858	Feces	72.40	7.99	7.22	8.63	3.76	1.28	13.47	2.10	1.437

TABLE 145.—*Weight, composition, and heat of combustion of food and feces—Metabolism experiment No. 76.*

[Quantities of food per day.]

	Food.						Feces.	
	Milk (3841).[1]	Apple (3842).[1]	Orange juice (3843).[1]	Shredded wheat (3844).[1]	Gluten crackers (3845).[1]	Total for day.	Total for 3 days (3858).[1]	Average per day.
(a) Weight......grams	650.70	122.70	312.90	177.80	10.10	1274.20	332.80	110.93
(b) Water.........do	527.52	106.36	273.47	12.84	.32	920.51	240.95	80.32
(c) Protein........do	7.09	2.42	1.85	17.99	8.23	37.58	26.59	8.86
(d) Fat............do	67.61	....	....	3.11	.08	70.75	24.03	8.01
(e) Carbohydrates..do	46.98	13.57	36.30	140.66	1.28	238.79	28.72	9.57
(f) Ash............do	1.50	.35	1.28	3.20	.24	6.57	12.51	4.17
(g) Nitrogen......do	1.11	.43	.31	3.16	1.44	6.45	4.26	1.42
(h) Carbon........do	72.75	6.82	13.74	75.12	5.04	173.47	44.83	14.94
(i) Hydrogen......do	11.65	1.04	2.44	12.09	.74	27.96	6.99	2.33
(j) Oxygen (by difference) grams	36.17	7.70	21.66	71.39	2.32	139.24	23.26	7.75
(k) Heat of combustion, calories	843	65	150	728	55	1841	478	159

[1] Laboratory number.

TABLE 146.—*Elements absorbed from food—Metabolism experiment No. 76.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Mar. 11, 1905.						
Food and drink:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Solids in food	353.69	6.45	173.47	27.96	139.24	6.57
Water in food	920.51	....	....	103.01	817.50	....
Water in drink	1021.10	....	....	114.26	906.84	....
Total	2295.30	6.45	173.47	245.23	1863.58	6.57
Feces:						
Solids	30.61	1.42	14.94	2.33	7.75	4.17
Water	80.32	....	....	8.99	71.33	....
Total	110.93	1.42	14.94	11.32	79.08	4.17
Absorbed[1]	2184.37	5.03	158.53	233.91	1784.50	2.40

[1] For March 12, 1905, the amounts of hydrogen and oxygen absorbed are 236.42 and 1804.39 grams respectively; for March 13, 1905, the corresponding amounts are 239.44 and 1828.37 grams.

Amounts of ingredients of food absorbed, and corresponding amounts of body materials.—A comparison of the protein, fat, and carbohydrates absorbed from the food, obtained by the usual method, i. e., by deducting the quantities of these compounds in the feces from those in the food, with the quantities computed as body material absorbed is given in table 147. The data for all days are identical.

TABLE 147.—*Amounts of ingredients of food absorbed, and body materials derived from them—Metabolism experiment No. 76.*

[Quantities per day.]

	(a) Food.	(b) Feces.	(c) Absorbed (a−b).	(d) Body material.[1]
Protein grams	37.58	8.86	28.72	30.18
Fat do	70.75	8.01	62.74	76.78
Carbohydrates do	238.79	9.57	229.22	190.01
Ash do	6.57	4.17	2.40	2.40
Energy calories	1841	159	1682	1699

[1] The amounts of water absorbed as calculated by the formulæ were as follows: March 11, 1885.45 grams; March 12, 1907.87 grams; March 13, 1934.86 grams.

Energy of material absorbed from food.—The protein, fat, and carbohydrates of the absorbed food when computed to the basis of body material yielded for each day the following amounts of energy: From protein, 171 calories; from fat, 732 calories; and from glycogen, 796 calories, a total of 1699 calories. The agreement of the energy thus computed with that determined from the heat of combustion of the food and feces is perhaps as close as could be expected, the error being approximately 1 per cent.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

The comparison indicated by the above heading is shown in table 148.

TABLE 148.—*Comparison of changes in body-weight with balance of income and outgo—Metabolism experiment No. 76.*

	Mar. 11-12.	Mar. 12-13.	Mar. 13-14.	Total for 3 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Food	1274.20	1274.20	1274 20	3822.60	1274.20
(*b*) Water consumed	1021.10	1043.50	1070.50	3135.10	1045.03
(*c*) Oxygen	527.25	500.16	507.08	1534.49	511.50
(*d*) Total ($a+b+c$)	2822.55	2817.86	2851.78	8492.19	2830.73
Outgo:					
(*e*) Urine[1]	1958.40	1131.30	1365.80	4455.50	1485.16
(*f*) Feces	....	....	28.10	28.10	9.37
(*g*) Carbon dioxide	551.36	560.44	608.39	1720.19	573.40
(*h*) Water of respiration and perspiration	616.81	582.30	611.39	1810.50	603.50
(*i*) Total ($e+f+g+h$)	3126.57	2274.04	2613.68	8014.29	2671.43
(*j*) Gain (+) or loss (−) of body material ($d-i$)	−304.02	+543.82	+238.10	+477.90	+159.30
(*k*) Gain (+) or loss (−) of body weight	−305	+526	+262	+483	+161

[1] The data in this line should not be confounded with urine data in other tables. See explanation, p. 66.

BALANCE OF INTAKE AND OUTPUT.

The usual division of the balance indicated under this head is shown in tables 149 and 150. There was a comparatively large gain to the body of

TABLE 149.—*Distribution of intake and outgo of water—Metabolism experiment No. 76.*

Date.	Outgo from the body. (*a*) Water of urine and feces.	(*b*) Water of respiration and perspiration.	(*c*) Total ($a+b$).	Balance of preformed water. (*d*) Preformed (katabolized) water in outgo.	(*e*) Intake in food and drink.	(*f*) Loss of preformed water ($d-e$).	(*g*) Water of oxidation of organic hydrogen ($c-d$).
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 11-12	1695.2	616.8	2312.0	2120.6	1941.6	179.0	191.4
Mar. 12-13	1290.4	582.3	1872.7	1678.6	1964.0	[2]−285.4	194.1
Mar. 13-14	[1]1595.1	611.4	2206.5	[1]2000.9	1991.0	[3] 9.9	205.6
Total, 3 days	4580.7	1810.5	6391.2	5800.1	5896.6	[2] −96.5	591.1
Av. per day	1526.9	603.5	2130.4	1933.4	1965.5	[2] −32.1	197.0

[1] Water in feces passed on the third day assumed as 19 grams. In obtaining this amount it has been assumed that the feces contained 72.4 per cent of water.
[2] Gain.
[3] Water of feces taken into account.

preformed water on the second day, while the losses on the other 2 days were small. The protein balance shows a daily loss throughout the experiment,

which indicates that the 30.18 grams of protein as body material furnished by the food was insufficient. There was an average loss of fat accompanied by a large average gain in carbohydrates. The body, however, was practically in carbon equilibrium. The energy furnished by the food was less by 154 calories per day than that actually resulting from the katabolism of body material.

TABLE 150.—*Balance of intake and output of nutrients, ash, and energy—Metabolism experiment No. 76.*

	Mar. 11-12, 1905.	Mar. 12-13, 1905.	Mar. 13-14, 1905.	Total for 3 days.	Average per day.
Body protein:					
(a) Computed from elements absorbed from food....grams..	30.18	30.18	30.18	90.54	30.18
(b) Katabolized. ....do....	61.02	42.90	46.92	150.84	50.28
(c) Loss to body (a—b)....do....	30.84	12.72	16.74	60.30	20.10
Body fat:					
(d) Computed from elements absorbed from food....grams..	76.75	76.80	76.79	230.34	76.78
(e) Katabolized...........do....	137.95	101.92	66.67	306.54	102.18
(f) Gain (+) or loss (—) to body (d—e)...............grams..	—61.20	—25.12	+10.12	—76.20	—25.40
Body carbohydrates:					
(g) Computed from elements absorbed from food....grams..	190.05	189.98	190.00	570.03	190.01
(h) Katabolized...........do....	56.37	131.62	217.47	405.46	135.15
(i) Gain (+) or loss (—) to body (g—h)..............grams..	+133.68	+58.36	—27.47	+164.57	+54.86
Ash:					
(j) In food absorbed.....grams..	2.40	2.40	2.40	7.20	2.40
(k) Eliminated in urine....do....	1.74	1.84	3.69	7.27	2.42
(l) Gain (+) or loss (—) to body (j—k)..............grams..	+.66	+.56	—1.29	—.07	—.02
Energy:					
(m) Of food absorbed (determined)............calories..	1682	1682	1682	5046	1682
(n) Heat production plus potential energy of urine.calories..	1892	1794	1822	5508	1836
(o) Loss to body (m—n)...do....	210	112	140	462	154

METABOLISM EXPERIMENT NO. 77.

This experiment was the last of the series of calorimeter experiments made with S. A. B.

Fasting experiment No. 75 was followed by the 3-day food experiment (No. 76) reported above. The latter ended at 7 a. m., March 14, 1905. From this time until the evening of April 7, the subject ate a liberal diet freely selected, and was engaged in light occupation about the laboratory. During this period all the food was sampled and the urine and feces were collected. This food experiment outside the calorimeter constituted nitrogen metabolism experiment No. 1 reported beyond.

On the evening of April 7, S. A. B. entered the calorimeter chamber with the intention of making a 10-day fast. He had recovered his weight, and his general physical condition seemed good. As the experiment progressed, however, his mental condition became such that it seemed wise to discontinue the fast at the end of the fourth day. This accorded with the wishes of the subject, and the experiment was therefore stopped at 7 a. m., April 12. No food was eaten in the calorimeter following the fast, but a second nitrogen metabolism experiment was carried on for 2 weeks following experiment No. 77. (See nitrogen metabolism experiment No. 2 reported beyond.)

Notes from diary, pulse records, and records of body movements.—The notes from the subject's diary are interesting as showing the condition of the subject. Whether the symptoms recorded were actual or the result of hypochondria, the diary seems to offer positive evidence that the subject passed a most miserable existence in the calorimeter during the time of this experiment. The statements in the diary are more or less in accord with the observations taken by telephone. The records of pulse taken as heretofore by the subject himself and the record of body movements are also given below. Wide fluctuations are noticeable in the pulse rate and the record was not completed for the fourth day of the fast.

Notes from diary.

April 7, 1905 (preliminary night):

9 p. m. Entered calorimeter. It feels warm in here.

April 8, 1905:

7h15m a. m. Did not sleep well. Tongue coated and bad taste in mouth which I have not had since last experiment.

7h35m a. m. Defecation.

10 p. m. Have passed a very comfortable day.

April 9, 1905:

7h15m a. m. Slept better than previous night. Felt too warm all night. My tongue is commencing to swell and is coated. Sweet taste in mouth. Removed rectal thermometer.

7h30m a. m. I feel rather weak and my nerves are unstrung. I am chewing gum, but do not like it very well.

8h15m a. m. Tried to defecate.

8h18m a. m. Commenced wearing rectal thermometer.

April 9, 1905: (cont.)

11 a. m. I feel very sleepy; will lie down on bed.

1 p. m. Had a 2-hour nap; feel a little better.

3^h5^m p. m. Rectal thermometer is commencing to feel uncomfortable.

5^h25^m p. m. Removed rectal thermometer.

5^h30^m p. m. Drank water. I hiccough and feel a little nausea.

9^h30^m p. m. Took an enema.

11 p. m. The weak feeling of the morning gradually passed away.

April 10, 1905:

7^h15^m a. m. I did not sleep well, as wearing the rectal thermometer made me uncomfortable. My tongue is swollen and coated. Sweetish taste in mouth. Eyes are bright and clear. Do not feel as weak as yesterday morning.

10^h5^m a. m. Feel weak. Will lie down.

1 p. m. Slept 3 hours.

2^h15^m p. m. I feel a little nausea after chewing gum.

8 p. m. Have had an intermittent pain of the heart since yesterday. When pain was gone, palpitation set in and head would commence to ache.

11 p. m. Have been feeling indisposed all day; have a feeling of nausea. Believe I made a mistake in fasting with a good appetite. All the other fasts were begun with no appetite.

April 11, 1905:

7^h20^m a. m. Did not sleep very well; do not feel as well as in my former fasts. My heart and stomach are acting queerly. Feel weak and can not hold up my head. Tongue swollen and somewhat coated.

8 a. m. Temperature (sublingual) 98.6° F. Have palpitations of the heart, and a gnawing at the stomach.

11 a. m. Have been sleeping since 8^h15^m a. m.

11^h15^m a. m. Have a bad headache.

4^h10^m p. m. Feel faint and dizzy; my head swims.

6^h5^m p. m. Feel very badly. Head swims, and I have pains from the back of the neck to forehead.

7^h50^m p. m. Felt very miserable all day. Was faint and dizzy.

Pulse rate—Experiment No. 77.[1]

Time.	Pulse rate.	Time.	Pulse rate.	Time.	Pulse rate.
Apr. 8, $7^h 30^m$ a.m..	74	Apr. 9, $8^h 00^m$ a.m..	82	Apr. 10, $4^h 08^m$ p.m..	61
8 20 a.m..	63	10 07 a.m..	62	8 00 p.m..	64
10 00 a.m..	61	4 00 p.m.	62	10 00 p.m..	70
12 00 noon.	63	6 00 p.m..	60	Apr. 11, 7 30 a.m..	88
2 10 p.m..	60	8 00 p.m..	61	8 00 a.m..	88
4 00 p.m..	54	10 00 p.m..	62	11 05 a.m..	84
6 00 p.m..	57	Apr. 10, 7 30 a.m..	84	1 10 p.m..	72
8 00 p.m..	57	8 00 a.m..	88	5 30 p.m..	69
10 05 p.m..	52	10 00 a.m..	82		
Apr. 9, 7 30 a.m..	88	2 00 p.m..	78		

[1] Pulse taken while sitting.

Movements of subject, duration 4 days, from Apr. 8, 7 a. m., to Apr. 12, 7 a. m., 1905.

April 8.

A. M.	
$7^h 02^m$ – 7 08	rise, open curtain, urinate, weigh self, etc.
7 10	dress, raise table, sit, read.
7 12	food aperture, sit.
7 15	count pulse, write.
7 20	drink.
7 30	count pulse.
7 36	defecate.
$7^h 38^m$	telephone.
7 44	food aperture, adjust thermometer, drink.
8 00	read.
8 20	count pulse.
8 48	drink.
9 02	food aperture.
9 04	telephone, sit.
9 20	move about.
9 24	play mandolin.
$9^h 52^m$	drink.
10 00	count pulse.
10 04	telephone, food aperture.
10 08	read.
10 18	play mandolin.
10 36	stop playing.
11 02	move in chair.
11 08	telephone.
11 10	drink.
11 12	telephone.

Movements of subject.—Continued.

April 8 (cont.)

Time	Movement
A. M.	
$11^h 14^m$	rise, move about.
11 18	sit.
11 48	rest head on arms.
12 00	count pulse.
P. M.	
$12^h 02^m$	food aperture.
12 06	food aperture, telephone.
12 20	food aperture.
12 24	read.
12 40	drink.
12 50	asleep with head on arms.
1 04	move about, urinate.
1 06	food aperture.
1 10	move about, move chair, sit.
1 18	read.
1 32	food aperture.
1 36	write.
1 42	telephone.
1 46	telephone.
1 48	write.
2 10	count pulse.
2 30	drink.
4 00	count pulse.
4 04	stand.
4 08	stand, doctor count pulse.
4 10	drink, sit.
4 16	food aperture.
4 18	telephone.
4 20	food aperture.
4 26	read.
5 04	move about, urinate.
5 05	drink.
5 06	sit.
5 08	read.
6 00	count pulse.
6 35	drink.
7 02	urinate.
7 04	telephone.
7 05	food aperture.
7 14	telephone, food aperture.
7 30	food aperture.
7 50	move about.
8 00	count pulse.
8 12	telephone.
8 40	drink.
10 05	count pulse.
10 07	drink.
10 10	rise, urinate.
10 12	lower table.
10 16	open bed, play mandolin.
P. M.	
$10^h 30^m$	stop playing, recline.
11 04	rise, undress, urinate, retire.

April 9.

Time	Movement
A. M.	
$7^h 00^m$	rise, urinate.
7 02 } 7 09 }	weigh self, etc.
7 12	dress, raise table.
7 15	remove thermometer.
7 16	telephone.
7 18	food aperture.
7 20	drink.
7 32	food aperture.
7 50	drink.
7 58	food aperture.
8 00	count pulse.
8 04	read.
8 12	move about.
8 15	attempt to defecate.
8 18	adjust thermometer.
8 20	telephone.
8 22	read.
8 25	drink.
8 40	food aperture.
8 42	read.
9 02	head on table.
9 10	read.
9 30	drink.
10 07	count pulse.
10 16	telephone.
10 18	food aperture.
10 22	asleep.
11 00	move about, drink.
11 02	rise, move about.
11 04	lower table.
11 06	open bed, urinate.
11 08	lie, asleep.
11 36	turn over.
P. M.	
$1^h 00^m$	rise, count pulse.
1 04	food aperture, lie.
1 08	telephone.
1 12	food aperture.
1 14	move about.
1 16	sit.
1 18	rise.
1 20	lie.
1 22	read.
1 42	sit.
1 44	fold bed, raise table.
1 46	sit, read.
2 04	telephone.
P. M.	
$2^h 08^m$	read.
3 02	write.
3 05	drink.
3 06	read.
3 16	telephone.
3 18	stand.
3 24	move chair, sit.
3 26	doctor count pulse.
3 30	food aperture.
3 32	sit, read.
4 00	count pulse.
4 28	telephone.
4 30	rise, move.
4 32	sit, blood sampled.
4 36	rise.
4 38	quiet.
4 40	food aperture, sit, read.
5 06	head on table, asleep.
5 20	sit, write.
5 22	remove thermometer.
5 26	rise, move about.
5 28	food aperture, urinate.
5 30	drink, lean on table, write.
5 32	stand.
5 36	sit, head on table.
5 38	sit, food aperture.
5 40	move about, food aperture.
5 42	move about, sit.
5 50	drink.
5 54	food aperture.
5 56	sit, read.
6 00	count pulse.
7 02	urinate, food aperture.
7 09	food aperture.
7 16	telephone.
7 18	move about.
7 45	drink.
8 00	count pulse.
8 33	telephone.
9 06	food aperture.
9 08	move about, open music rack, play mandolin.
9 12	telephone.
9 14	play mandolin.
9 24	food aperture.
9 26	move about.
9 28	coat off, close curtain.
9 32	enema, defecate.
9 48	open curtain, coat on.

***Movements of subject*.—Continued.**

April 9 (cont.)

P. M.

$9^{h}\,50^{m}$ telephone.
9 52 play mandolin.
10 00 count pulse.
10 12 mandolin in case, fold rack.
10 14 move about, drink, lower table, open bed, recline.
11 00 adjust thermometer.
11 04 move about, urinate, undress, close curtain.

April 10.

A. M.

$7^{h}\,00^{m}$ rise, urinate.
7 04 } weigh self, etc.
7 08 }
7 12 raise table.
7 14 move about, sit.
7 15 drink.
7 18 food aperture.
7 21 food aperture.
7 24 telephone.
7 30 count pulse.
7 46 sit, write.
8 00 count pulse.
9 32 drink.
9 34 write, head on table.
9 36 doze.
10 00 count pulse.
10 04 sit.
10 05 drink.
10 08 rise, move about, urinate.
10 10 lower table.
10 12 open bed, lie.
10 30 telephone.
10 33 sit, food aperture.
10 34 asleep.

P. M.

$1^{h}\,00^{m}$ wake, rise, food aperture.
1 04 urinate.
1 06 lie.
2 00 count pulse.
2 02 rise, move about.
2 06 telephone.
2 08 write.
2 15 drink.
2 28 read.
2 36 head on table.
2 46 sit.
3 02 telephone.
3 04 rise, stand, blood sampled.

P. M.

$3^{h}\,18^{m}$ food aperture, sit, read.
3 42 telephone.
3 44 read.
3 52 telephone.
3 54 stand.
4 00 sit.
4 02 rise, food aperture, sit, doctor count pulse.
4 06 food aperture, sit.
4 08 count pulse.
4 10 drink.
4 20 rise, urinate.
4 22 food aperture, sit.
4 28 read.
4 42 asleep.
5 00 sit.
5 02 rise, lower table.
5 04 open bed, lie.
5 10 asleep.
6 20 awake, lean on elbow.
6 22 lie.
6 24 sit, food aperture.
6 26 lie.
6 30 take temperature.
7 30 take temperature.
7 55 drink.
8 02 sit, count pulse.
8 25 write.
8 26 food aperture.
8 28 telephone.
8 30 lie.
9 08 food aperture.
9 15 take temperature.
10 00 count pulse.
11 00 take temperature, write.
11 02 rise, urinate, arrange bed.
11 04 undress, retire.

April 11.

A. M.

$7^{h}\,00^{m}$ rise, urinate.
7 02 } weigh self, etc.
7 09 }
7 10 dress.
7 12 raise table, sit.
7 16 rise, food aperture.
7 18 sit.
7 20 drink.
7 22 comb hair.
7 30 count pulse.
7 38 head on table.
8 00 count pulse, take temperature.
8 04 head on table.
8 06 sit.

A. M.

$8^{h}\,08^{m}$ rest.
8 12 write.
8 14 lower table, open bed.
8 16 lie.
8 18 telephone.
8 20 asleep.
11 02 awake, lean on elbow.
11 04 sit.
11 05 count pulse, take temperature.
11 10 food aperture.
11 12 shake thermometer.
11 14 lie.
11 15 drink.
11 22 telephone.
11 34 sit, write.
11 36 lie.
11 44 sit.
11 50 read.

P. M.

$12^{h}\,04^{m}$ recline, read.
12 06 telephone.
12 12 sit, read.
12 20 recline, read.
12 26 lie, asleep.
1 00 sit, rise, urinate, take temperature.
1 04 move about, sit, food aperture.
1 10 count pulse.
1 18 lie.
1 24 move about, drink.
1 26 asleep.
3 00 turn over.
3 02 telephone.
3 06 stand.
3 08 sit, doctor count pulse.
3 10 sit.
3 12 recline.
3 14 telephone.
3 16 lie.
4 00 sit.
4 02 lie.
4 06 sit.
4 10 write.
4 12 lie, sit.
4 14 stand, sit.
4 16 lie.
4 24 sit, recline.
4 26 sit.
4 32 lie.
4 38 turn over.
4 42 turn over.
5 00 lean on elbow.
5 04 sit.

Movements of subject.—Continued.

April 11 (cont.)	
P. M.	
5h 06m	move.
5 10	sit, head on hands.
5 12	lie.
5 18	sit, move.
5 20	sit, write.
5 22	take temperature.
5 24	sit, count pulse.
5 36	lie.
5 38	sit, telephone.
5 40	lie.
5 44	sit, food aperture.
5 46	drink, food aperture.
5 50	sit.
5 54	telephone.
P. M.	
6h 02m	lie.
6 04	sit.
6 06	write.
6 08	food aperture.
6 10	eat ice.
6 12	telephone.
6 16	food aperture.
6 18	read.
6 22	lean on elbow.
6 44	telephone.
7 02	telephone, food aperture.
7 04	rise, urinate.
7 06	sit, read.
7 08	drink, telephone, recline.
P. M.	
7h 50m	drink, write.
9 02	sit.
9 04	telephone.
9 06	sit.
9 14	rise, read.
9 36	telephone.
9 40	sit, read.
10 00	lie.
10 04	rise, open bed, move about.
10 08	sit.
10 18	write.
10 32	lie.
11 02	rise, undress, urinate.
11 04	close curtain.

Drinking-water.—The quantities of drinking-water consumed are recorded in table 151. As in experiments Nos. 75 and 76, the subject measured the

TABLE 151.—*Record of water consumed—Metabolism experiment No. 77.*

Date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	Total for day.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 8–9....	395.7	175.0	381.9	200.0	99.5	397.8	175.0	223.3	2048.2
Apr. 9–10...	397.8	200.0	197.1	....	175.0	224.9	200.0	198.1	1592.9
Apr. 10–11...	175.0	219.8	....	250.0	144.1	....	229.8	....	1018.7
Apr. 11–12...	175.0	....	116.1	199.7	....	77.3[1]	393.9	....	962.0

[1] Includes 51.4 grams ice.

amount of water each time he drank so that the quantities consumed from period to period are definitely known. The amounts diminished from day to day.

A small portion of ice eaten on the last day of the experiment is included in the amounts recorded in the table.

URINE.

In this experiment, owing to pressure of other work, no analyses were made of the urine for different periods of the day though the usual method of collecting the urine was followed. The specific gravity and reaction were determined only for the daily composites and not by periods as heretofore. On all days the reaction was acid.

The amounts of urine by periods were as follows:

Weight and specific gravity of urine by periods—Metabolism experiment No. 77.

Date.	7 a. m. to 1 p. m.	1 to 7 p. m.	7 to 11 p. m.	11 p. m. to 7 a. m.	Total for day.	Specific gravity.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
Apr. 8– 9........	755.8	600.3	502.2	712.0	2570.3	1.0072
Apr. 9–10........	863.4	411.6	218.2	684.4	2177.6	1.0101
Apr. 10–11........	533.2	401.4	260.1	379.6	1574.3	1.0132
Apr. 11–12........	312.1	311.6	173.4	359.5	1156.6	1.0178

Determinations were made only on the composite samples for each day. These include the inorganic and ethereal, and neutral sulphur and preformed creatinine and creatine. The total weights of materials excreted are recorded in table 152.

TABLE 152.—*Weight, composition, and heat of combustion of urine—Metabolism experiment No. 77.*

	Apr. 8-9.	Apr. 9-10.	Apr. 10-11.	Apr. 11-12.	Total for 4 days.
(*a*) Weight....................grams..	2570.3	2177.6	1574.3	1156.6	7478.8
(*b*) Water.......................do...	2528.15	2122.94	1520.30	1102.01	7273.40
(*c*) Solids, *a*—*b*..................do...	42.15	54.66	54.00	54.59	205.40
(*d*) Ash..........................do...	13.88	11.98	10.55	9.14	45.55
(*e*) Organic matter, *c*—*d*..........do...	28.27	42.68	43.45	45.45	159.85
(*f*) Nitrogen.....................do...	8.81	10.78	10.98	11.45	42.02
(*g*) Carbon.......................do...	7.97	13.94	13.70	14.57	50.18
(*h*) Hydrogen in organic matter.....do...	2.06	3.05	2.99	3.24	11.34
(*i*) Oxygen (by difference) in organic matter, *e*—(*f*+*g*+*h*).......grams..	9.43	14.91	15.78	16.19	56.31
(*j*) Phosphorus...................do...	.817	1.206	1.088	1.150	4.261
Phosphoric acid (P_2O_5):					
(*k*) By fusion...................do...	1.871	2.763	2.492	2.633	9.759
(*l*) By titration................do...	1.992	2.982	2.515	2.769	10.258
(*m*) Sulphur......................do...	.477	.652	.685	.662	2.476
Sulphur trioxide (SO_3)					
(*n*) Total.......................do...	1.190	1.628	1.710	1.651	6.179
(*o*) Inorganic and ethereal.......do...	.934	1.322	1.485	1.425	5.166
(*p*) Neutral, *n*—*o*...............do...	.256	.306	.225	.226	1.013
(*q*) Creatinine (preformed).........do...	1.202	1.027	.968	.848	4.045
(*r*) Total creatinine...............do...	1.342	1.343	1.383	1.386	5.454
(*s*) Creatine[1] (preformed) *r*—*q*.....do...	.140	.316	.415	.538	1.409
(*t*) Chlorine.....................do...	5.294	1.671	1.919	.647	9.531
(*u*) Sodium chloride...............do...	8.737	2.757	3.167	1.068	15.729
(*v*) Heat of combustion........calories..	90	157	157	170	574

[1] In terms of creatinine.

ELIMINATION OF WATER-VAPOR AND CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

The usual determinations of water-vapor, carbon dioxide, and oxygen were made and recorded. The results appear in tables 153 and 154.

The total amounts per day of water of respiration and perspiration remained much more nearly constant than for the corresponding 4 days of any preceding experiment.

TABLE 153.—*Record of water of respiration and perspiration—Metabolism experiment No. 77.*

Date.	Period.	(a) Total am'nt of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.[1]
1905.	Preliminary:	*Grams.*	*Grams.*
Apr. 8.....	1 a.m..........	39.0	...
	1 a.m. to 3 a.m.	36.2	78.0
	3 a.m. 5 a.m.	34.5	77.6
	5 a.m. 7 a.m.	30.8	66.5
	Total 6 hours	....	222.1
Apr. 8–9..	7 a.m. to 9 a.m.	33.9	74.0
	9 a.m. 11 a.m.	31.2	60.4
	11 a.m. 1 p.m.	26.8	56.5
	1 p.m. 3 p.m.	26.2	57.7
	3 p.m. 5 p.m.	25.6	54.7
	5 p.m. 7 p.m.	24.8	54.2
	7 p.m. 9 p.m.	23.9	53.7
	9 p.m. 11 p.m.	25.5	45.4
	11 p.m. 1 a.m.	24.3	52.5
	1 a.m. 3 a.m.	25.0	47.7
	3 a.m. 5 a.m.	26.0	57.5
	5 a.m. 7 a.m.	28.7	55.3
	Total......	....	669.6
Apr. 9–10..	7 a.m. to 9 a.m.	32.7	77.8
	9 a.m. 11 a.m.	27.8	48.4
	11 a.m. 1 p.m.	24.4	49.7
	1 p.m. 3 p.m.	27.2	50.1
	3 p.m. 5 p.m.	26.1	47.2
	5 p.m. 7 p.m.	26.5	48.3
	7 p.m. 9 p.m.	25.5	54.8
	9 p.m. 11 p.m.	29.3	58.3
	11 p.m. 1 a.m.	24.3	53.1
	1 a.m. 3 a.m.	27.9	50.9
	3 a.m. 5 a.m.	24.5	51.2
	5 a.m. 7 a.m.	26.3	47.9
	Total......	....	637.7
1905.		*Grams.*	*Grams.*
Apr. 10–11.	7 a.m. to 9 a.m.	33.0	68.4
	9 a.m. 11 a.m.	28.2	47.5
	11 a.m. 1 p.m.	25.1	50.3
	1 p.m. 3 p.m.	25.5	54.7
	3 p.m. 5 p.m.	27.0	49.0
	5 p.m. 7 p.m.	24.6	50.1
	7 p.m. 9 p.m.	24.7	51.3
	9 p.m. 11 p.m.	24.6	52.1
	11 p.m. 1 a.m.	26.1	43.6
	1 a.m. 3 a.m.	25.3	52.6
	3 a.m. 5 a.m.	26.6	45.0
	5 a.m. 7 a.m.	27.6	52.9
	Total......	....	617.5
Apr. 11–12.	7 a.m. to 9 a.m.	29.2	50.2
	9 a.m. 11 a.m.	25.6	51.4
	11 a.m. 1 p.m.	27.6	49.1
	1 p.m. 3 p.m.	24.8	50.8
	3 p.m. 5 p.m.	26.7	47.1
	5 p.m. 7 p.m.	27.5	59.4
	7 p.m. 9 p.m.	24.4	50.8
	9 p.m. 11 p.m.	24.9	57.2
	11 p.m. 1 a.m.	24.9	53.0
	1 a.m. 3 a.m.	26.6	54.7
	3 a.m. 5 a.m.	25.2	50.9
	5 a.m. 7 a.m.	25.3	52.0
	Total......	....	626.6

[1] Allowance has been made for water lost from the chair, bedding, and miscellaneous articles as follows: April 8-9, 25.12 grams; April 9-10, 39.02 grams; April 10-11, 49.22 grams; April 11-12, 29.22 grams.

The data recorded in table 154 show that the carbon dioxide elimination gradually diminished as the experiment proceeded. There was a slight increase in the consumption of oxygen on the second day, a diminished amount on the third, and constancy for the third and fourth days.

TABLE 154.—*Record of carbon dioxide and oxygen—Metabolism experiment No. 77.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 8.......	1 a. m.............	20.4	....	959.3	....
	1 a. m. to 3 a. m..	19.4	41.9	956.4	37.0
	3 a. m. 5 a. m..	18.1	42.3	956.9	37.1
	5 a. m. 7 a. m..	20.2	45.3	970.3	36.3
	Total...........	....	129.5	....	110.4
Apr. 8-9.....	7 a. m. to 9 a. m..	26.9	65.6	960.5	60.9
	9 a. m. 11 a. m..	27.3	56.4	963.5	51.6
	11 a. m. 1 p. m..	21.6	48.6	968.6	45.9
	1 p. m. 3 p. m..	22.2	52.9	966.9	49.0
	3 p. m. 5 p. m..	23.2	53.6	974.0	47.2
	5 p. m. 7 p. m..	19.9	46.1	973.7	45.7
	7 p. m. 9 p. m..	20.7	50.6	984.0	45.2
	9 p. m. 11 p. m..	23.8	51.9	978.6	52.8
	11 p. m. 1 a. m..	16.6	38.4	985.8	32.5
	1 a. m. 3 a. m..	18.3	39.5	983.0	36.4
	3 a. m. 5 a. m..	19.3	48.2	983.1	45.2
	5 a. m. 7 a. m..	22.9	47.7	984.7	43.6
	Total...........	....	599.5	....	556.0
Apr. 9-10 ...	7 a. m. to 9 a. m..	25.6	65.9	974.4	68.8
	9 a. m. 11 a. m..	23.1	43.6	981.8	40.0
	11 a. m. 1 p. m..	17.4	38.4	982.1	41.3
	1 p. m. 3 p. m..	24.5	54.6	975.1	51.8
	3 p. m. 5 p. m..	25.2	45.4	970.8	52.5
	5 p. m. 7 p. m..	25.1	48.4	976.2	50.5
	7 p. m. 9 p. m..	22.1	52.8	983.3	50.9
	9 p. m. 11 p. m..	27.7	62.5	969.5	61.3
	11 p. m. 1 a. m..	16.1	37.6	977.7	27.5
	1 a. m. 3 a. m..	21.3	42.1	971.5	48.8
	3 a. m. 5 a. m..	19.7	42.3	977.0	33.9
	5 a. m. 7 a. m..	21.8	43.3	968.8	44.2
	Total...........	....	576.9	....	571.5
Apr. 10-11...	7 a. m. to 9 a. m..	27.0	63.1	947.5	70.0
	9 a. m. 11 a. m..	25.2	47.5	950.0	43.1
	11 a. m. 1 p. m..	18.7	40.9	952.8	30.2
	1 p. m. 3 p. m..	21.0	50.2	936.6	39.1
	3 p. m. 5 p. m..	23.9	50.1	927.0	49.3
	5 p. m. 7 p. m..	18.7	41.8	931.0	40.2
	7 p. m. 9 p. m..	20.9	48.3	931.3	46.4
	9 p. m. 11 p. m..	20.4	47.0	931.2	46.3
	11 p. m. 1 a. m..	20.5	40.1	920.2	35.7
	1 a. m. 3 a. m..	18.3	42.5	926.1	41.6
	3 a. m. 5 a. m..	21.5	41.6	921.3	41.4
	5 a. m. 7 a. m..	21.0	43.5	915.0	47.4
	Total...........	....	556.6	....	530.7

TABLE 154.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 11-12...	7 a. m. to 9 a. m..	27.2	52.8	914.9	44.9
	9 a. m. 11 a. m..	20.0	41.2	924.9	38.7
	11 a. m. 1 p. m..	24.6	49.4	917.3	48.7
	1 p. m. 3 p. m..	18.5	40.5	921.2	37.2
	3 p. m. 5 p. m..	24.0	45.9	914.7	45.9
	5 p. m. 7 p. m..	21.8	48.8	912.2	51.5
	7 p. m. 9 p. m..	17.0	42.8	920.4	36.7
	9 p. m. 11 p. m..	19.7	52.1	913.5	55.3
	11 p. m. 1 a. m..	17.8	43.4	921.2	38.7
	1 a. m. 3 a. m..	18.6	40.2	913.0	41.4
	3 a. m. 5 a. m..	20.5	45.1	915.0	50.7
	5 a. m. 7 a. m..	19.8	42.5	923.6	41.9
	Total...........	....	544.7	....	531.6

ELEMENTS KATABOLIZED IN THE BODY.

The elements katabolized in the body, obtained by the methods previously described are given in table 155.

TABLE 155.—*Elements katabolized in body—Metabolism experiment No. 77.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
First day, Apr. 8, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air.......	556.02	....	....	....	556.02	....
Outgo:						
Water in urine.............	2528.15	....	....	282.90	2245.25	....
Solids in urine..............	42.15	8.81	7.97	2.06	9.43	13.88
Water of respiration [1].......	669.61	....	....	74.93	594.68	....
Carbon dioxide............	599.46	....	163.49	....	435.97	....
Total..................	3839.37	8.81	171.46	359.89	3285.33	13.88
Loss..................	3283.35	8.81	171.46	359.89	2729.31	13.88
Second day, Apr. 9, 1905.						
Income: Oxygen from air.......	571.55	....	....	....	571.55	....
Outgo:						
Water in urine.............	2122.94	....	....	237.56	1885.38	....
Solids in urine..............	54.66	10.78	13.94	3.05	14.91	11.98
Water of respiration [1].......	637.73	....	....	71.36	566.37	....
Carbon dioxide............	576.90	....	157.34	....	419.56	....
Total..................	3392.23	10.78	171.28	311.97	2886.22	11.98
Loss..................	2820.68	10.78	171.28	311.97	2314.67	11.98

[1] Includes also water of perspiration.

TABLE 155.—*Elements katabolized in body*—Continued.

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
Third day, Apr. 10, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	530.72	....	....	....	530.72	....
Outgo:						
Water in urine	1520.30	....	....	170.12	1350.18	....
Solids in urine	54.00	10.98	13.70	2.99	15.78	10.55
Water of respiration[1]	617.52	....	....	69.10	548.42	....
Carbon dioxide	556.62	....	151.80	....	404.82	....
Total	2748.44	10.98	165.50	242.21	2319.20	10.55
Loss	2217.72	10.98	165.50	242.21	1788.48	10.55
Fourth day, Apr. 11, 1905.						
Income: Oxygen from air	531.59	....	....	....	531.59	....
Outgo:						
Water in urine	1102.01	....	....	123.31	978.70	....
Solids in urine	54.59	11.45	14.57	3.24	16.19	9.14
Water of respiration[1]	626.56	....	....	70.11	556.45	....
Carbon dioxide	544.74	....	148.56	....	396.18	....
Total	2327.90	11.45	163.13	196.66	1947.52	9.14
Loss	1796.31	11.45	163.13	196.66	1415.93	9.14

[1] Includes also water of perspiration.

Elements and materials katabolized in the body.—A summary of the elements katabolized and the compounds computed from them is given in table 156. The high carbohydrate katabolism on the third and fourth days is of especial interest as compared with results in other fasting experiments.

TABLE 156.—*Elements and materials katabolized in body—Metabolism experiment No. 77.*

Date.	(a) Nitrogen.	(b) Carbon.	(c) Hydrogen.	(d) Oxygen.	(e) Water.	(f) Protein.	(g) Fat.	(h) Carbohydrates (as glycogen).	(i) Ash.
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 8– 9	8.81	171.46	359.89	2729.31	2989.75	52.86	134.97	92.70	13.88
Apr. 9–10	10.78	171.28	311.97	2314.67	2558.28	64.68	171.88	14.85	11.98
Apr. 10–11	10.98	165.50	242.21	1788.48	1945.78	65.88	137.65	58.92	10.55
Apr. 11–12	11.45	163.13	196.66	1415.93	1540.46	68.70	149.85	29.21	9.14
Total, 4 days.	42.02	671.37	1110.73	8248.39	9034.22	252.12	594.35	195.68	45.55

Balance of water.—In table 157 the distribution of intake and output of water is shown. Allowance has not been made for water in feces passed on the first and second days of the experiment.

TABLE 157.—*Distribution of intake and outgo of water—Metabolism experiment No. 77.*

Date.	Outgo from the body.			Balance of preformed water.			(*g*) Water of oxidation of organic hydrogen (*c*—*d*).
	(*a*) Water of urine.	(*b*) Water of respiration and perspiration.	(*c*) Total (*a*+*b*).	(*d*) Preformed (katabolized) water in outgo.[1]	(*e*) Intake in drink.	(*f*) Loss of preformed water (*d*—*e*).[1]	
1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 8–9	2528.2	669.6	3197.8	2989.8	2048.2	941.6	208.0
Apr. 9–10	2122.9	637.7	2760.6	2558.3	1592.9	965.4	202.3
Apr. 10–11	1520.3	617.5	2137.8	1945.7	1018.7	927.0	192.1
Apr. 11–12	1102.0	626.6	1728.6	1540.4	962.0	578.4	188.2
Total for 4 days	7278.4	2551.4	9824.8	9034.2	5621.8	3412.4	790.6
Average per day	1818.3	637.9	2456.2	2258.6	1405.5	853.1	197.6

[1] No allowance has been made for water in feces passed on the first and second days.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

The balance of income and outgo is compared with the fluctuations in body-weight and as in the other fasting experiments the feces passed during the experiment have not been included in obtaining the outgo. The comparisons of the measured and computed losses show unsatisfactory agreement on the first 2 days.

TABLE 158.—*Comparison of changes of body weight with balance of income and outgo—Metabolism experiment No. 77.*

	Apr. 8-9.	Apr. 9-10.	Apr. 10-11.	Apr. 11-12.	Total for 4 days.	Average per day.
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
(*a*) Water consumed	2048.20	1592.90	1018.70	962.00	5,621.80	1405.45
(*b*) Oxygen	556.02	571.55	530.72	531.59	2,189.88	547.47
(*c*) Total (*a*+*b*)	2604.22	2164.45	1549.42	1493.59	7,811.68	1952.92
Outgo:						
(*d*) Urine[1]	2099.80	2205.20	1879.10	1176.70	7,360.80	1840.08
(*e*) Feces[2]	144.40	35.30	....	....	179.70	44.93
(*f*) Carbon dioxide	599.46	576.90	556.62	544.74	2,277.72	569.43
(*g*) Water of respiration and perspiration	669.61	637.73	617.52	626.56	2,551.42	637.85
(*h*) Total (*d*+*f*+*g*)	3368.87	3419.83	3053.24	2348.00	12,189.44	3047.36
(*i*) Loss of body material (*c*—*h*)	764.15	1255.38	1503.82	854.41	4,377.76	1094.44
(*j*) Loss of body weight	736	1190	1502	868	4,296	1074

[1] The data in this line should not be confounded with urine data in other tables. See explanation, p. 66.
[2] Not included in the total outgo. See p. 120.

OUTPUT OF HEAT.

The total heat production, shown in column *d* of table 159, was fairly constant throughout the 4 days of this experiment, the difference between the maximum and minimum amounts being but 67 calories.

TABLE 159.—*Summary of calorimetric measurements and total heat production—Metabolism experiment No. 77.*

Date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
1905.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Apr. 8........	1 a.m. to 3 a.m...	77.2	46.2	[2] + 7.2	[2] 130.6
	3 a.m. 5 a.m...	76.2	45.9	[2] +12.0	[2] 134.1
	5 a.m. 7 a.m...	90.0	39.4	[2] −20.4	[2] 109.0
	Total..........	243.4	131.5	[2] − 1.2	[2] 373.7
Apr. 8–9......	7 a.m. to 9 a.m...	180.5	45.1	−30.0	195.6
	9 a.m. 11 a.m...	147.3	37.0	+ 1.4	185.7
	11 a.m. 1 p.m...	130.1	34.7	− 5.9	158.9
	1 p.m. 3 p.m...	125.7	35.4	− .6	160.5
	3 p.m. 5 p.m...	136.1	33.6	− .5	169.2
	5 p.m. 7 p.m...	138.5	33.3	− .2	171.6
	7 p.m. 9 p.m...	129.1	33.0	−12.6	149.5
	9 p.m. 11 p.m...	135.3	28.1	−19.8	143.6
	11 p.m. 1 a.m...	63.6	32.3	+15.8	111.7
	1 a.m. 3 a.m...	78.3	29.5	+12.2	120.0
	3 a.m. 5 a.m...	98.2	35.3	+23.7	157.2
	5 a.m. 7 a.m...	106.6	34.0	+10.3	150.9
	Total	1469.3	411.3	− 6.2	1874.4
Apr. 9–10.....	7 a.m. to 9 a.m...	187.6	48.0	−40.2	195.4
	9 a.m. 11 a.m...	136.4	30.6	−13.6	153.4
	11 a.m. 1 p.m...	101.6	31.3	+ 8.3	141.2
	1 p.m. 3 p.m...	142.1	31.6	− 8.1	165.6
	3 p.m. 5 p.m...	143.2	29.9	+ 9.9	183.0
	5 p.m. 7 p.m...	135.6	30.5	− 2.7	163.4
	7 p.m. 9 p.m...	117.1	34.4	−11.9	139.6
	9 p.m. 11 p.m...	158.9	36.4	−35.0	160.3
	11 p.m. 1 a.m...	81.0	33.3	+15.9	130.2
	1 a.m. 3 a.m...	94.8	32.0	+ 9.8	136.6
	3 a.m. 5 a.m...	105.9	32.3	+22.7	160.9
	5 a.m. 7 a.m...	102.9	30.3	+16.8	150.0
	Total..........	1507.1	400.6	−28.1	1879.6
Apr. 10–11....	7 a.m. to 9 a.m...	192.6	42.9	−48.0	187.5
	9 a.m. 11 a.m...	142.7	30.5	− 6.1	167.1
	11 a.m. 1 p.m...	85.9	32.2	− 1.1	117.0
	1 p.m. 3 p.m...	130.6	34.8	+ .7	166.1
	3 p.m. 5 p.m...	144.0	31.4	+ 4.8	180.2
	5 p.m. 7 p.m...	99.5	32.1	+ 1.4	133.0
	7 p.m. 9 p.m...	122.8	32.8	−13.2	142.4
	9 p.m. 11 p.m...	129.4	33.3	−18.8	143.9
	11 p.m. 1 a.m...	84.2	28.3	+19.8	132.3
	1 a.m. 3 a.m...	98.7	33.6	+ 6.3	138.6
	3 a.m. 5 a.m...	121.6	29.1	+16.3	167.0
	5 a.m. 7 a.m...	100.5	33.7	+30.7	164.9
	Total..........	1452.5	394.7	− 7.2	1840.0

[1] See pp. 42-49. [2] Not corrected for changes in body temperature and weight.

TABLE 159.—*Summary of calorimetric measurements and total heat production*—Continued.

Date.	Period.	(*a*) Heat measured in terms C_{20}.	(*b*) Heat used in vaporization of water.	(*c*) Sum of heat corrections.[1]	(*d*) Total heat production (*a*+*b*+*c*).
1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Apr. 11-12....	7 a.m. to 9 a.m...	166.9	31.2	−52.8	145.3
	9 a.m. 11 a.m...	108.4	31.9	− 5.6	134.7
	11 a.m. 1 p.m...	139.1	30.5	+ 2.1	171.7
	1 p.m. 3 p.m...	112.3	31.5	− 2.7	141.1
	3 p.m. 5 p.m...	123.0	29.3	+16.6	168.9
	5 p.m. 7 p.m...	135.2	36.6	− 8.1	163.7
	7 p.m. 9 p.m...	123.6	31.5	−10.6	144.5
	9 p.m. 11 p.m...	132.1	35.3	−19.1	148.3
	11 p.m. 1 a.m...	81.0	32.8	+20.9	134.7
	1 a.m. 3 a.m...	85.5	33.8	+15.1	134.4
	3 a.m. 5 a.m...	115.2	31.6	+10.6	157.4
	5 a.m. 7 a.m...	120.5	32.2	+10.0	162.7
	Total..........	1442.8	388.2	−23.6	1807.4

[1] See pp. 42-49.

BALANCE OF ENERGY.

A comparison of the energy derived from different sources with the total heat production for the 4 days of the experiment is given in table 160. The agreement is not very satisfactory save on the first day, but owing to the compensating discrepancies the average difference for the whole experiment is but — 0.8 per cent.

TABLE 160.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiment No. 77.*

Date.	Energy derived from different sources.						(*g*) Total heat produced.	Energy from body material greater (+) or less (—) than output.	
	From body protein.								
	(*a*) Energy of protein katabolized.	(*b*) Potential energy of urine.	(*c*) Net energy (*a*—*b*).	(*d*) From body fat.	(*e*) From body glycogen.	(*f*) Total (*c*+*d*+*e*).		(*h*) Amount (*f*—*g*).	(*i*) Proportion (*h*÷*g*).
1905.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Apr. 8- 9....	299	90	209	1288	388	1885	1874	+ 11	+0.6
Apr. 9-10....	365	157	208	1640	62	1910	1880	+ 30	+1.6
Apr. 10-11....	372	157	215	1313	247	1775	1840	− 65	−3.5
Apr. 11-12....	388	170	218	1430	122	1770	1807	− 37	−2.0
Total, 4 days.	1424	574	850	5671	819	7340	7401	− 61	....
Av. per day..	356	143	213	1418	205	1835	1850	− 15	−0.8

TABLE 161.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiment No. 77.*

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated. (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f ÷ g).
1905.								
Apr. 8:								
Preliminary:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1 a.m. to 3 a.m.	[1]130.6	37.0	28.3	41.9	32.1	21.3	25.9	0.82
3 a.m. 5 a.m.	[1]134.1	37.1	27.7	42.3	31.5	21.6	25.9	.83
5 a.m. 7 a.m.	[1]109.0	36.3	33.3	45.3	41.6	23.0	25.4	.91
Total.......	[1]373.7	110.4	29.5	129.5	34.7	65.9	77.3	0.86
Apr. 8–9:								
7 a.m. to 9 a.m.	195.6	60.9	31.1	65.6	33.5	33.4	42.6	0.78
9 a.m. 11 a.m.	185.7	51.6	27.8	56.4	30.4	28.7	36.1	.80
11 a.m. 1 p.m.	158.9	45.9	28.9	48.6	30.6	24.8	32.1	.77
1 p.m. 3 p.m.	160.5	49.0	30.5	52.9	32.9	26.9	34.3	.79
3 p.m. 5 p.m.	169.2	47.2	27.9	53.6	31.7	27.3	33.1	.83
5 p.m. 7 p.m.	171.6	45.7	26.6	46.1	26.8	23.4	32.0	.73
7 p.m. 9 p.m.	149.5	45.2	30.2	50.6	33.8	25.7	31.6	.81
9 p.m. 11 p.m.	143.6	52.8	36.8	52.0	36.2	26.5	37.0	.72
11 p.m. 1 a.m.	111.7	32.5	29.1	38.4	34.4	19.6	22.7	.86
1 a.m. 3 a.m.	120.0	36.3	30.3	39.5	32.9	20.1	25.5	.79
3 a.m. 5 a.m.	157.2	45.2	28.8	48.2	30.7	24.5	31.6	.78
5 a.m. 7 a.m.	150.9	43.7	29.0	47.6	31.6	24.3	30.6	.79
Total.......	1874.4	556.0	29.7	599.5	32.0	305.2	389.2	0.78
Apr. 9–10:								
7 a.m. to 9 a.m.	195.4	68.8	35.2	65.9	33.7	33.6	48.2	0.70
9 a.m. 11 a.m.	153.4	40.0	26.1	43.6	28.4	22.2	28.0	.79
11 a.m. 1 p.m.	141.2	41.3	29.3	38.4	27.2	19.6	28.9	.68
1 p.m. 3 p.m.	165.6	51.8	31.3	54.6	33.0	27.8	36.3	.77
3 p.m. 5 p.m.	183.0	52.5	28.7	45.4	24.8	23.1	36.8	.63
5 p.m. 7 p.m.	163.4	50.5	30.9	48.4	29.6	24.7	35.4	.70
7 p.m. 9 p.m.	139.6	50.9	36.4	52.8	37.8	26.9	35.6	.71
9 p.m. 11 p.m.	160.3	61.3	38.2	62.5	39.0	31.8	42.9	.74
11 p.m. 1 a.m.	130.2	27.5	21.1	37.6	28.9	19.1	19.3	.99
1 a.m. 3 a.m.	136.6	48.8	35.7	42.1	30.8	21.4	34.1	.63
3 a.m. 5 a.m.	160.9	33.9	21.1	42.3	26.3	21.5	23.7	.91
5 a.m. 7 a.m.	150.0	44.2	29.5	43.3	28.9	22.0	30.9	.71
Total.......	1879.6	571.5	30.4	576.9	30.7	293.7	400.1	0.73
Apr. 10–11:								
7 a.m. to 9 a.m.	187.5	70.0	37.3	63.1	33.7	32.1	49.0	0.66
9 a.m. 11 a.m.	167.1	43.1	25.8	47.5	28.4	24.2	30.1	.80
11 a.m. 1 p.m.	117.0	30.2	25.8	40.9	34.9	20.8	21.1	.98
1 p.m. 3 p.m.	166.1	39.1	23.6	50.2	30.2	25.5	27.4	.93
3 p.m. 5 p.m.	180.2	49.3	27.4	50.1	27.8	25.5	34.5	.74
5 p.m. 7 p.m.	133.0	40.2	30.3	41.8	31.4	21.3	28.2	.76
7 p.m. 9 p.m.	142.4	46.4	32.6	48.3	33.9	24.6	32.5	.76
9 p.m. 11 p.m.	143.9	46.3	32.2	47.0	32.6	23.9	32.4	.74
11 p.m. 1 a.m.	132.3	35.7	27.0	40.1	30.3	20.4	25.0	.82
1 a.m. 3 a.m.	138.6	41.6	30.0	42.5	30.7	21.7	29.1	.74
3 a.m. 5 a.m.	167.0	41.4	24.8	41.6	24.9	21.2	29.0	.73
5 a.m. 7 a.m.	164.9	47.4	28.7	43.5	26.4	22.2	33.2	.67
Total.......	1840.0	530.7	28.8	556.6	30.3	283.4	371.5	0.76

[1] See table 159, p. 218.

TABLE 161.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Date and period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b+a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d+a).	(f) Volume of carbon dioxide eliminated (d×0.5091)	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f+g).
1905. Apr. 11-12:	*Cals.*	*Grams.*		*Grams.*		*Liters*	*Liters.*	
7 a.m. to 9 a.m.	145.2	44.9	30.9	52.8	36.3	26.9	31.5	0.85
9 a.m. 11 a.m.	134.7	38.7	28.8	41.2	30.6	21.0	27.1	.77
11 a.m. 1 p.m.	171.8	48.7	28.3	49.4	28.8	25.2	34.1	.74
1 p.m. 3 p.m.	141.0	37.2	26.4	40.6	28.8	20.6	26.0	.79
3 p.m. 5 p.m.	168.9	45.9	27.2	45.9	27.2	23.3	32.1	.73
5 p.m. 7 p.m.	163.7	51.5	31.4	48.8	29.8	24.8	36.0	.69
7 p.m. 9 p.m.	144.6	36.7	25.4	42.8	29.6	21.8	25.7	.85
9 p.m. 11 p.m.	148.3	55.3	37.3	52.1	35.1	26.5	38.7	.68
11 p.m 1 a.m.	134.7	38.7	28.7	43.4	32.2	22.1	27.1	.82
1 a.m. 3 a.m.	134.4	41.4	30.8	40.2	29.9	20.5	29.0	.71
3 a.m. 5 a.m.	157.4	50.7	32.2	45.1	28.7	23.0	35.4	.65
5 a.m. 7 a.m.	162.7	41.9	25.8	42.5	26.2	21.6	29.4	.74
Total.......	1807.4	531.6	29.4	544.8	30.1	277.3	372.1	0.75

RELATIONS BETWEEN CARBON DIOXIDE ELIMINATION, OXYGEN CONSUMPTION, AND HEAT PRODUCTION.

The oxygen thermal quotients recorded in table 161 show no unusual fluctuations aside from the very low quotient of the third day[1] and the average for the 4 days, 29.6, is not particularly different from those observed in other experiments. The carbon dioxide thermal quotient for 24 hours is highest on the first day and gradually diminishes each day to the end of the experiment. As is usual in the fasting experiments the respiratory quotient is highest on the first day. It averages 0.75 for the last 3 days.

[1] See special discussion under Energy Balance, in Part 3 of this report.

A SERIES OF TWO-DAY FASTING EXPERIMENTS WITH SEVEN SUBJECTS. METABOLISM EXPERIMENTS NOS. 79-83, 85, AND 89.

The fasting experiments thus far given in this report furnished data for studying the metabolism during inanition of but 3 persons. It seemed important therefore to make studies with a large number of men, in order to verify some of the deductions rendered possible by the previous experiments. Particularly was it desired to ascertain the length of time required by different individuals for the transition from katabolism with food to fasting katabolism, i. e., the duration of the transitional period. More information was also sought concerning the effect of inanition on the pulse and observations were made of the influence of fasting on the respiration, strength, and the onset of fatigue.

Accordingly, 7 fasting experiments of 2 days' duration were made with different subjects during the autumn and winter of 1905-1906, the results of the series being given below. Following experiments Nos. 83, 85, and 89, 24-hour food experiments were made, the data of which are not included in this publication.

The 7 men who served as subjects in this series of 2-day fasts were students in Wesleyan University, young men in good health. Two of them had previously been in the calorimeter for short periods of about 24 hours, but the others were inexperienced. It seemed best, therefore, to accustom the men to the environment of the calorimeter and hence each subject entered the chamber approximately 12 hours before the experiment proper began.

Measurements of subjects.—In order to give some idea of the physique of the subjects and their muscular development, the measurements of each man, as recorded in the university gymnasium, are shown below. The measurements of H. E. S., A. H. M., and H. C. K., were taken at times very near to that of their respective experiments. The others were measured somewhat earlier, 8 months previous in the case of H. R. D., and the considerable period of about 3 years and 2 months in the case of N. M. P. D. W. was a football and baseball player and had unquestionably developed to an extent beyond that shown by the measurements here given.

Notes from diaries.—Each subject kept a diary during his stay in the calorimeter. The diaries have been abstracted, and such notes as relate to the physical and mental condition are shown below.

Measurements of subjects—Metabolism experiments Nos. 79-83, 85, and 89.

	H. E. S.	C. R. Y.	A. H. M.	H. C. K.	H.R.D.[1]	N. M. P.	D. W.
Date	Oct. 20, 1905.	Dec. 9, 1904.	Oct. 23, 1905.	Oct. 12, 1905.	Apr. 10, 1905.	Oct. 18, 1902.	Oct. 23, 1903.
Age at date	$19^{y.}$	$18^{y.}\ 10^{m.}$	$24^{y.}$	$21^{y.}\ 4^{m.}$	$17^{y.}$	$18^{y.}\ 10^{m.}$	$19^{y.}\ 11^{m.}$
Weight ....kilograms..	55.9	68.5	62.8	72	55.9	64.8	74.3
Height ....centimeters..	177.5	169.8	178.6	181.2	171.2	177.1	179.7
Sternum........do......	....	....	....	....	141.4	146.6	147.6
Navel ....do......	....	....	....	....	100.5	105.7	106.5
Pubis........do......	....	....	....	....	88.7	88.8	89.8
Sitting........do......	....	.. .	....	....	90.7	93.5	95.7
Knees........do......	....	....	....	....	42.6	46.2	44.8
Length:							
Shoulders to elbow.centim'rs.	....	....	....	....	36.7	38.3	39.2
Elbow to tips........do......	....	....	....	....	48.5	48.1	46.9
Arm reach........do......	....	....	....	....	177.8	183	181.2
Right foot........do......	....	....	....	....	26.1	26.6	27.6
Left foot........do......	....	....	...	....	26.2	26.6	28.4
Girth:							
Head ....centimeters..	....	....	....	....	57.5	57.5	56.5
Neck........do......	33.8	36.7	34.5	35.5	35	34.1	36.2
Upper chest:							
Repose ......centimeters..	81	95	85	87	83.5	84	93
Depressed........do......	78.8	86.5	81.1	86.1	....	82	87.5
Inflated........do......	84.9	100.5	89.5	88.9	87.5	88.5	97
Lower chest:							
Repose ......centimeters..	71.1	80.5	73.2	77.5	....	....	....
Depressed........do......	65	79	71.5	76.3	78	80	77.4
Inflated........do......	76	87.8	80.6	82	82.5	86	86.2
Waist........do......	68.7	75	64.5	73.9	68	70.5	77.9
Hips........do......	....	....	....	....	87.5	92.5	101.2
Right biceps........do......	24.5	26.8	26.5	27.5	27	27.3	32.2
Flexed........do......	26.8	30.5	28.5	31.4	....	....	....
Left biceps........do......	23.5	26	26	27.2	26.5	26.6	31
Flexed........do......	26	28.5	28.5	30	....	....	...
Right arm........do......	....	....	....	....	....	22.5	27.5
Left arm........do......	....	....	....	....	....	22.3	28.1
Right elbow........do......	....	....	....	....	24	20.6	23
Left elbow........do......	....	....	....	....	24	20.4	24.3
Right forearm........do......	....	....	....	....	25	24.3	28.5
Contracted........do......	25.8	27.8	27	28	....	....	....
Left forearm........do......	....	....	....	....	24	23.4	27.4
Contracted........do......	24.3	27.5	27	28	.. .	....	....
Right wrist........do......	....	....	....	....	17	15.6	17.9
Left wrist........do......	....	....	....	....	17	15.5	17.8
Right thigh........do......	47.5	57.5	53	57.5	48	52.2	58.3
Left thigh........do......	46.1	56	53	54.5	48	53	57.7
Right knee........do......	....	....	....	....	35.5	38.5	39.5
Left knee........do......	....	....	....	....	35.5	38.5	39.2
Right calf........do......	32	36.5	35	36.5	31.5	35	36.5
Left calf........do......	31	35.5	34.5	35.9	31.5	35.5	36.2
Right instep........do......	....	....	...	....	22.5	23.4	26.5
Left instep........do......	....	....	....	....	22.5	23.6	26.5
Breadth:							
Head ....centimeters..	....	....	....	....	15.5	15.6	15.5
Neck........do......	....	....	....	....	10	11.2	11.6
Shoulders........do......	39.4	38.7	38.8	42.6	39.2	40.5	43.6
Chest........do......	25.7	28.6	26.4	28.3	....	26.6	28.6
Waist........do......	21.6	26.3	21.7	24.2	23.2	25.4	27.2
Hips........do......	32.6	33.5	32	32.3	31.2	35	35.4
Depth:							
Chest ....centimeters..	16.8	18.7	17.7	19.3	19.2	18.6	18.2
Abdomen........do......	17.3	18.3	16.6	18.9	17	18.3	17.6

[1] Depth of head, 19.9 centimeters.

Notes from diaries.

Experiment No. 79, H. E. S.

October 13, 1905:

7 a. m. Rose; stomach seems somewhat empty.

7^h40^m a. m. Was getting very hungry but after I took a drink of water the feeling was not so noticeable.

11^h35^m a. m. Am getting rather hungry and my belt hangs very loosely about me.

1^h15^m p. m. Do not feel hungry now.

4^h14^m p. m. All the afternoon I have had a queer feeling on my lungs every time I drew a breath longer than usual. Am not especially hungry but feel as if I could eat. Lay down from 5^h10^m to 7^h2^m p. m.

October 14, 1905:

7 a. m. Am very sick at my stomach except when lying down.

7^h2^m p. m. Have felt weak and tired all day, and have been dizzy when I stood up.

11^h2^m p. m. Went to bed; got up at some time in the night, about 1 a. m. I believe. Thought it was morning.

Experiment No. 80, O. R. Y.

October 26, 1905 (preliminary night):

Entered calorimeter chamber about 8 p. m. Attempted to read but was so sleepy that I had to stop; had slept only 5 hours the night before. Retired at 11 p. m.

October 27, 1905:

7 a. m. Arose at signal; followed the usual morning routine. Sat down and read.

7^h45^m a. m. Took strength test. Feel all right this morning; not hungry at all.

10^h30^m a. m. Began to read, sitting near window.

12^h20^m p. m. Lay down on bed; slept some of the time.

11^h20^m p. m. Drank about one-half glass of cold water before retiring, though not very thirsty.

October 28, 1905:

7 a. m. Do not feel ill, but have bad taste in mouth. Am a little weaker than yesterday, but not especially hungry.

7^h20^m a. m. Drank some water, which I vomited some time between 8 and 9 a. m.

11^h20^m a. m. Reclined on bed, sleeping part of the time.

6 p. m. Have been lying down most of the afternoon. Felt all right except for bad taste in mouth.

8 p. m. Went to sleep about 8 or 8^h30^m p. m. and didn't wake up until 11 p. m.

11^h20^m p. m. Drank some cold water; it tasted good. During the latter part of the night I slept but very little; was anxious for morning to come. Had bad taste in mouth whenever I was awake.

Experiment No. 81, A. H. M.

November 21, 1905:

7^h30^m a. m. Slept all through the night; well rested. Awoke at about 6^h15^m a. m., lay awake until 7. Feel perfectly normal this morning; have good appetite. Felt somewhat thirsty, drank a little water.

1^h10^m p. m. Studied and read almost all of the morning. Feel very well. Could eat a pretty good dinner now, but fasting does not trouble me very much.

7^h5^m p. m. Feel just the same as at noon; just about as hungry. Feel perfectly strong. Read and studied during the afternoon.

November 22, 1905:

7^h45^m a. m. Slept well through the whole night; woke at about 6^h15^m a. m., rose at 7 a. m. Don't feel quite as strong this morning. Was thirsty when I got up; drank some water and feel better, though somewhat weak when standing. Am all right when sitting down. Head perfectly clear.

1 p. m. Feel stronger now than when I rose this morning, began to feel better after I had been about an hour and a half. Think perhaps the water made me feel better. Spent nearly all the morning writing an essay. Read a little.

7^h10^m p. m. Feel all right, not very hungry now. Lay down on bed from 1 p. m. to 6; had a few naps. Probably asleep about half the time. Have been reading since 6.

11^h2^m p. m. Have been lying down all the evening, reading a part of the time. Feel well.

Notes from diary.—Continued.

November 23, 1905:

7 a. m. Rested well during night; woke up twice, once about 3 a. m. and about 5 a. m. but went to sleep soon each time. Feel well, but a little thirsty.

Experiment No. 82, H. C. K.

November 23, 1905 (preliminary night):

11 p. m. Made up bed and retired; slept pretty well but woke up rather early. Had a pain in my back which I think was due to lying in one position for so long a time. Also had a pain in my stomach which was more noticeable whenever I took a deep breath.

November 24, 1905:

7 a. m. Arose. Mouth and throat were very dry.

7^h50^m a. m. Taking a deep breath causes a pain in my throat; otherwise I feel well though my mouth is dry.

9^h20^m a. m. Wrote letters until 2^h45^m p. m.

1^h15^m p. m. Drank some water.

7^h25^m p. m. Slept a little while. Have been lying down and now feel much better.

7^h30^m p. m. Studied until 10^h15^m.

10^h30^m p. m. Studied until 11 p. m.

11^h2^m p. m. Retired.

November 25, 1905:

7^h2^m a. m. This night passed better than the last, though I awoke early. Backache and stomach-ache were not so bad as the night before. Very thirsty. Felt rather warm, on arising, almost like a fever.

7^h30^m a. m. Defecated.

7^h50^m a. m. Drank fresh water; feel much better. Feverish feeling has left me and I feel quite comfortable.

1 p. m. Drank some water. Slightly dizzy when I stood up.

3^h50^m p. m. Lay down.

7^h5^m p. m. Got up and drank some water. Have a slight headache, also pain in the stomach; otherwise am all right.

7^h30^m p. m. Feel fairly comfortable. Lying on the respiration apparatus has made my chest and back rather sore. The rectal thermometer does not trouble me.

11^h5^m p. m. Made up bed and retired.

Experiment No. 83, H. R. D.

December 4, 1905 (preliminary night):

9^h15^m p. m. Wrote till 10^h25^m.

11 p. m. Retired; did not get to sleep for about half an hour, then slept very soundly. Awoke and looked at my watch at 4 a. m.; slept on till about 6^h30^m, then lay awake till the signal to rise was given.

December 5, 1905:

7^h30^m a. m. Feel very comfortable and contented. Stomach somewhat empty, but not uncomfortable and have no particular desire for food. Feel strong; most of my movements are slow, however, for fear of entangling the apparatus attached to me.

7^h40^m a. m. Read for about 5 minutes, then wrote a short letter, but took considerable time about it as I was in doubt as to what to say. Am beginning to notice everything that passes. Am much entertained with watching the people who pass the window.

8^h15^m a. m. Some water was passed in. I drank it all. No strange taste.

9 a. m. Lay down till 11, sleeping a great part of the time.

11^h10^m a. m. Rose, and drank a bottle of water, which tasted very good. Feel perfectly well, and am not hungry. Took dynamometer test.

1^h10^m p. m. Lay down, feeling perfectly well; went to sleep.

3^h30^m p. m. Awoke, but did not get up.

4^h10^m p. m. Got up. Feel well, but less ambitious and lively than when I lay down. Slightly unpleasant feeling in my head, more like dizziness than headache, but not exactly either; not serious.

4^h15^m p. m. Received a bottle of water, of which I drank about a third. Feel chilly at times and decidedly unpleasant ever since I got up.

4^h30^m p. m. Lay down again; more comfortable when lying down. Have a slight feeling of nausea; hungry. Went to sleep with blanket over me.

Notes from diary.—Continued.

December 5, 1905 (cont.)

7h10m p. m. Drank some water; it was absolutely tasteless, but cool and refreshing. Am greatly refreshed by my sleep. Feel perfectly well again, head perfectly clear; less inclined to move rapidly than I was this morning, but am quite as comfortable. Not hungry now except when I think of something in particular to eat.

9h25m p. m. Feel well and comfortable; no pain, nothing to annoy me.

9h30m p. m. Lay down; slept most of time till signal at 11 p. m.

11 p. m. Undressed and retired. It must have been nearly 12 before I fell asleep, then slept soundly. Awoke at 5 a. m., looked at my watch, and went to sleep again.

December 6, 1905:

7 a. m. Feel rather faint and weak this morning, but have no pain and am quite comfortable, but hungry.

8h5m a. m. Very unpleasant taste in the mouth. Drank some water and went on writing.

9 a. m. Lay down, after drinking some water; went to sleep almost at once.

10h30m a. m. Awoke, but lay still.

11 a. m. Arose; took dynamometer test.

12 a. m. Feel much better than when I arose this morning; that is, feel stronger. Still feel somewhat faint but very comfortable.

1 p. m. Lay down; feel well.

2h50m p. m. Awoke.

4h10m p. m. Got up. Feel well; a little weak, but no more so than this morning. Quite comfortable.

7 p. m. Feel well and rather stronger than earlier in the day, but somewhat faint even yet.

7h 10m p. m. Took dynamometer test.

7h45m p. m. Am not in pain but am decidedly faint. It requires very noticeable effort to hold up my head, also to write. Left hand weak and rather unsteady, right hand somewhat better. Not at all pleasant sitting up.

8 p. m. Saw friends at the window; greatly pleased to see them. Made me forget all about how I felt.

9 p. m. Lay down, feeling comfortable, though a little faint and hungry; went to sleep.

11 p. m. Awoke at signal. Retired and went to sleep very shortly. Awoke early, could not tell when, but probably about 5h30m a. m., then went to sleep again.

Experiment No. 85, N. M. P.

December 8, 1905 (preliminary night):

Read until 9h45m p. m.; light not good. Very comfortable; stomach feels full.

December 9, 1905:

Did not sleep very well. Woke at 1h30m, 3h30m, and 4h30m a. m., staying awake about three-quarters of an hour the last time. The reason for waking was that I kicked off the loose blanket and became chilly. Rose at 7. Drank some water at 7h40m. Slightly cool, but not uncomfortable.

9h15m a. m. Took dynamometer test and drank a little water.

9h30m a. m. Feel somewhat hungry.

12h15m to 12h20m p. m. Walked around the calorimeter and examined the apparatus.

12h20m p. m. Began to study mathematics.

1h25m p. m. Stopped studying. Made up bed and lay down, read and rested; slept a little.

4 p. m. Dynamometer test. Everything very comfortable; not feeling hungry except when I think about it. Read and rested until 7.

7 p. m. Studied, read, and wrote all the evening. Part of the time in chair and part of the time reclining on bed.

11 p. m. Am not feeling uncomfortable in any way nor particularly hungry.

December 10, 1905:

Slept better than the previous night; woke up twice, at 2h15m, and 4h30m a. m. or thereabout. The pneumograph makes me uncomfortable when I lie down.

7h50m a. m. Felt dizzy when I got up; my stomach seemed somewhat upset, and I felt weak. Drank some water. After sitting for a few minutes the dizziness ceased; the bilious feeling is also going. Desire to urinate noticeable as it was all day yesterday.

Notes from diary.—Continued.

December 10, 1905 (cont.)

8 a. m. Moved around. The water I drink tastes bad. Wrote letters from 8 to 9^h45^m a. m.

9^h45^m a. m. Lay down and read. Am feeling considerably better than when I first got up; water tastes better.

11^h15^m a. m. Have been reclining most of the time; began to sit at table and read.

12^h15^m p. m. Feel chilly, read and wrote at table until nearly 2^h30^m.

2^h30^m p. m. Lay down and rested and read until 7; slept a little.

7^h15^m p. m. Sat and read and wrote. Went to food aperture twice and telephoned some during the evening. My gums feel soft and a little sore; have a peculiar sensation in my abdomen. Don't feel exactly hungry, but feel empty. My chest is uncomfortable when I lie on a hard part of the pneumograph; feel tired particularly about the muscles in my lower side and back which comes, I suppose, from sitting up. Slight desire to defecate. Lay down about 10^h30^m but stayed up until then reading and writing.

11 p. m. Went to bed.

December 11, 1905:

Had great difficulty in getting to sleep last night; probably a little nervous. Was hot and sweaty and the pneumograph troubled me until 1 a. m. Woke up repeatedly and dozed again, then slept until 2 a. m., was awake a half hour. Slept until 4, but did not stay awake long; slept until 6^h15^m.

7 a. m. Rose and went through the usual routine of weighing. Do not feel dizzy, or sick, or uncomfortable in any way.

Experiment No. 89, D. W.

January 10, 1906:

Got into bed at 11^h11^m last night. Slept well until about 4 a. m. and dozed from that time until 7 a. m.

7 a. m. Feeling well except a little hazy, possibly due to loss of sleep. Lay down at 9^h10^m and had a very comfortable nap, which lasted until $12^h 30^m$ p. m. Still feel a little sleepy, but do not feel especially hungry as yet.

2^h45^m p. m. Have not felt hungry as yet. Lay down at 3^h5^m and had a slight nap; got up at 5^h30^m. Have not felt very hungry nor have I felt uncomfortable in any way; do not feel thirsty.

Lay down at 8^h15^m until 9^h15^m. Feel a little hungry for the first time. Retired at 11^h5^m.

January 11, 1906:

Woke up at 3^h45^m a. m. not feeling very well, and quite thirsty; took a large drink of water, which did not taste very good. Lay down again and dozed until 7 o'clock. Do not feel quite as lively as I did yesterday morning; somehow my stomach feels a litle queer and I feel tired in general. Drank a little water.

9^h10^m a. m. Was glad to lie down and had a short nap, waking at 11. Feel a little hungry now but water tastes bad, so that I don't care much about eating. Sat and read until 3^h5^m p. m. when I lay down. Am feeling rather hungry now. At 3^h5^m I lay down and slept until 5.

8^h5^m p. m. Felt a little weak after the strength test but otherwise am feeling very well. The test seemed a little harder than last night.

At 10^h23^m I had some fresh water passed in; it tasted much better than any of the water I had drunk before.

Retired at 11 p. m. but did not sleep very much. Tossed around considerably.

Pulse and respiration.—In all experiments previously included in this publication, each subject counted his own pulse and the respiration was not taken. The following records of pulse and respiration were obtained by means of the Fitz pneumograph, the use of which in these researches has already been explained. (See page 10.)

PULSE AND RESPIRATION.

Metabolism experiment No. 79.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Oct. 12			Oct. 13			Oct. 14		
P. M.			P. M.			P. M.		
$11^h 38^m$	..	13	$8^h 56^m$	..	19	$12^h 08^m$	..	19
Oct. 13			9 30	58	17	2 15	67	20
A. M.			10 26	..	19	3 40	..	19
$12^h 12^m$	..	12	11 50	60	17	5 45	78	18
12 46	..	11	11 53	66	18	8 35	..	20
1 23	54	11	11 58	..	17	9 12	60	18
2 46	..	14	Oct. 14			9 38	..	16
3 30	..	11	A. M.			10 00	59	16
4 14	..	10	$12^h 50^m$	..	18	11 30	63	19
4 46	..	11	1 25	63	18	11 54	..	17
5 20	..	10	2 00	..	17	Oct. 15		
9 46	55	..	3 10	..	19	A. M.		
11 00	55	13	3 52	..	19	$12^h 18^m$	..	18
P. M.			4 54	..	17	1 36	..	20
$1^h 48^m$	63	17	5 44	..	17	2 36	..	16
3 50	58	19	5 45	62	19	2 40	..	16
7 14	..	19	6 26	..	17	3 30	..	20
8 12	..	18	6 30	57	18	6 06	..	17
						6 45	..	18

PULSE AND RESPIRATION—Continued.

Metabolism experiment No. 80.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Oct. 26			Oct. 27			Oct. 28		
P. M.			P. M			P. M.		
$11^{h}45^{m}$	73	16	$7^{h}35^{m}$	62	..	$11^{h}30^{m}$	74	..
Oct. 27			9 00	52	13	11 44	..	18
A. M.			10 05	47	14	11 52	76	17
$12^{h}20^{m}$	..	14	10 35	..	14	Oct. 29		
12 50	..	14	11 45	59	18	A. M.		
12 59	73	13	Oct. 28			$12^{h}06^{m}$	77	17
1 24	..	14	A. M.			12 20	75	16
1 54	..	16	$12^{h}25^{m}$	59	14	12 23	79	..
1 58	67	20	12 55	63	13	12 24	75	..
2 16	59	13	1 25	65	17	12 37	77	16
2 26	..	14	2 00	58	14	12 48	81	20
2 52	..	13	2 32	58	15	12 50	86	..
3 02	58	14	3 00	63	20	12 59	75	15
3 28	..	14	3 40	60	14	1 21	72	15
3 52	..	14	4 23	..	17	1 34	71	16
3 59	62	13	4 32	78	19	1 40	73	15
4 26	..	15	5 00	65	15	1 55	91	19
4 53	50	13	5 30	68	15	2 11	72	17
5 10	..	13	6 10	68	14	2 24	77	16
5 28	..	14	6 40	70	14	2 37	71	16
6 00	..	13	8 10	87	19	2 50	71	15
6 08	52	13	8 13	97	..	3 00	73	16
6 15	68	14	8 42	90	17	3 17	81	21
6 54	..	14	9 56	64	16	3 36	73	15
8 45	..	17	10 27	80	16	3 53	97(?)	15
9 28	..	16	11 41	64	14	4 08	81	21
10 49	..	16	P. M.			4 15	86	..
11 32	..	17	$12^{h}10^{m}$	67	15	4 24	84	19
P. M.			3 33	..	20	4 36	89	18
$12^{h}17^{m}$	..	14	3 41	87	..	4 49	73	16
1 17	..	20	4 35	73	16	4 59	74	17
2 10	..	13	5 27	82	22	5 18	75	14
2 47	..	12	6 22	72	24	5 22	73	16
3 23	..	13	9 14	87	14	5 34	71	15
3 32	56	..	9 48	63	14	5 38	75	..
4 23	..	17	10 28	66	15	5 50	76	16
5 01	..	19	10 57	76	19	6 02	..	17
5 45	56	..	11 25	..	20	6 06	80	..
6 15	..	17	11 28	85	20	6 07	75	..
7 27	..	16						

PULSE AND RESPIRATION—Continued.
Metabolism experiment No. 81.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Nov. 20			Nov. 21			Nov. 22		
P. M.			P. M.			P. M.		
11h 27m	43	14	11h 37m	40	13	3h 44m	48	17
11 43	42	13	11 52	41	14	4 00	44	14
11 58	..	14	Nov. 22			4 18	47	17
Nov. 21			A. M.			4 32	48	17
A. M.			12h 09m	41	13	4 58	52	18
12h 04m	42	..	12 23	41	13	5 14	48	17
12 17	42	13	12 39	39	15	5 50	50	21
12 26	42	14	12 55	40	14	6 41	45	22
12 39	43	13	1 12	39	14	7 12	53	..
12 55	45	15	1 28	39	14	9 41	50	19
1 13	41	12	1 43	39	14	10 20	48	19
1 26	41	13	1 56	41	14	10 47	51	20
1 41	40	13	2 01	39	..	11 24	47	16
1 58	41	13	2 12	43	14	11 39	47	15
2 10	41	13	2 25	..	15	11 55	48	15
2 24	40	12	2 31	40	12	Nov. 23		
2 39	41	12	2 40	39	14	A. M.		
2 55	45	13	2 54	40	14	12h 11m	49	16
3 10	46	19	2 59	..	13	12 24	49	15
3 24	40	11	3 14	42	14	12 45	53	16
3 39	42	12	3 28	41	14	12 55	49	15
3 55	42	12	3 45	41	13	1 00	..	15
4 12	42	12	3 58	43	14	1 09	..	15
4 34	42	15	4 13	42	13	1 15	48	15
4 45	41	14	4 28	42	13	1 27	49	15
4 55	44	13	4 42	42	15	1 40	48	15
5 15	44	14	4 55	42	15	1 53	..	16
5 29	..	13	5 12	45	13	1 56	..	15
5 35	42	13	5 28	48	17	1 59	47	15
5 49	42	13	5 32	..	13	2 09	..	15
6 04	..	13	5 42	..	13	2 14	47	15
6 16	45	17	5 52	44	14	2 20	47	15
6 28	42	..	6 01	45	..	2 28	48	..
6 37	43	12	6 13	45	15	2 40	55	18
6 49	43	12	6 27	46	15	2 54	49	17
8 37	47	16	6 41	46	17	3 09	46	15
9 00	..	18	6 56	47	14	3 24	48	15
9 37	44	17	8 17	55	17	3 39	48	15
10 12	47	11	8 42	59	15	3 54	50	16
P. M.			8 57	64	..	4 08	..	17
12h 12m	46	..	9 26	60	..	4 11	..	15
1 38	43	20	9 46	..	17	4 14	53	21
2 04	39	..	9 58	61	..	4 27	49	16
2 16	48	13	10 19	57	20	4 31	51	13
2 48	59	11	10 34	58	..	4 41	..	13
4 02	44	13	10 57	53	20	4 45	49	14
4 26	42	11	11 20	54	..	4 55	50	14
5 01	45	12	11 41	55	16	5 12	51	18
5 28	39	12	11 56	50	17	5 22	..	15
6 00	47	..	P. M.			5 29	49	..
9 00	44	..	1h 06m	46	14	5 41	52	15
9 38	..	15	2 05	53	14	5 56	53	14
9 48	45	..	2 20	47	..	6 10	53	15
10 06	42	17	2 30	41	14	6 25	56	17
10 36	..	15	2 46	40	14	6 29	..	16
10 43	56	..	3 08	43	15	6 38	..	17
10 44	46	..	3 20	44	18	6 50	55	19
11 24	38	13	3 27	44	..	6 57	58	..

PULSE AND RESPIRATION—Continued.

Metabolism experiment No. 82.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Nov. 23			Nov. 24			Nov. 25		
P. M.			A. M.			A. M.		
6^{h} 59^{m}	59	23	5^{h} 25^{m}	53	16	1^{h} 39^{m}	50	17
7 13	64	25	5 39	54	17	2 02	50	18
7 26	66	22	5 57	53	18	2 13	55	21
7 47	67	20	6 08	..	15	2 33	51	18
7 58	60	21	6 25	56	17	2 45	52	19
8 13	..	22	6 29	..	16	2 56	54	19
8 17	..	23	6 38	..	17	3 18	65	18
8 23	65	21	6 43	51	16	3 25	57	20
8 30	61	..	6 55	55	15	3 41	56	18
8 43	73	22	8 14	64	23	3 55	55	18
8 57	68	20	8 27	52	19	4 10	56	19
9 10	64	18	8 41	69	20	4 26	55	19
9 26	61	23	8 57	61	23	4 38	56	19
9 31	58	..	9 20	70	24	4 56	55	19
9 48	53	16	9 53	68	24	5 12	56	19
10 00	52	17	10 08	59	23	5 27	63	19
10 15	..	17	10 18	72	23	5 38	..	17
10 26	59	21	10 30	63	25	5 45	57	..
10 34	58	20	10 54	72	23	5 54	55	17
10 45	59	21	11 12	69	23	6 09	58	18
10 56	58	22	11 52	72	24	6 23	59	19
11 16	49	20	P. M.			6 37	..	18
11 29	48	16	12^{h} 09^{m}	68	23	6 42	59	16
11 45	48	16	1 52	65	..	6 53	..	19
11 54	..	17	2 20	73	28	6 57	61	18
Nov. 24			2 46	65	24	8 09	73	24
A. M.			3 03	67	23	8 24	55	26
12^{h} 07^{m}	48	..	3 21	68	26	8 44	78	27
12 19	49	16	3 35	59	19	9 01	73	24
12 30	..	17	3 58	63	19	9 23	67	23
12 33	..	16	4 09	58	19	9 39	66	23
12 38	51	16	4 29	52	21	9 55	69	25
12 46	51	16	4 43	52	18	10 07	60	23
12 56	51	16	5 01	63	17	10 15	58	21
1 10	50	16	7 54	64	..	10 35	66	23
1 24	48	15	9 35	..	21	10 43	68	22
1 28	..	17	9 42	69	23	10 57	68	24
1 39	50	17	9 47	75	..	11 24	79	26
1 55	..	15	9 59	..	21	11 38	68	25
2 04	52	17	10 07	64	..	11 44	66	25
2 17	57	16	10 22	67	22	11 54	71	24
2 27	51	16	10 39	57	23	P. M.		
2 42	52	17	10 43	..	22	12^{h} 01^{m}	63	25
2 56	52	17	10 58	59	21	12 25	..	26
3 10	52	17	11 21	53	21	12 47	72	22
3 25	53	17	11 37	52	19	2 01	67	23
3 29	54	..	11 52	53	19	2 07	67	23
3 38	..	17	Nov. 25			2 16	63	22
3 44	58	18	A. M.			2 24	64	20
3 55	56	16	12^{h} 07^{m}	53	18	2 47	67	27
4 17	54	17	12 22	54	18	3 01	74	25
4 32	59	16	12 38	..	15	3 12	74	26
4 36	54	..	12 42	56	..	3 24	80	26
4 44	57	17	12 53	52	17	3 39	83	25
4 56	52	17	1 13	49	18	4 11	86	20
5 12	53	17	1 24	49	19	4 19	68	24

PULSE AND RESPIRATION—Continued.
Metabolism experiment No. 82—Continued.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Nov. 25			Nov. 25			Nov. 26		
P. M.			P. M.			A. M.		
$4^h 30^m$	62	20	$11^h 30^m$	76	..	$3^h 49^m$	59	..
4 37	67	19	11 40	60	20	3 57	62	20
4 45	64	20	11 55	60	20	4 15	62	19
5 08	61	20	Nov. 26			4 25	59	18
6 11	67	23	A. M.			4 40	68	17
6 26	..	22	$12^h 09^m$	60	19	4 56	78	20
6 31	81	..	12 25	60	19	4 59	84	..
6 44	70	23	12 41	67	16	5 00	74	..
7 00	72	..	12 43	63	..	5 09	..	20
7 15	80	26	12 47	58	..	5 14	71	..
8 35	70	..	12 55	56	18	5 16	79	..
9 40	85	28	12 59	..	18	5 17	67	..
9 43	76	..	1 10	59	19	5 25	73	21
9 53	..	25	1 27	56	20	5 28	66	..
9 57	81	24	1 41	57	18	5 39	..	19
10 08	..	27	1 55	60	19	5 43	69	..
10 10	84	25	2 17	64	20	5 54	..	21
10 13	88	..	2 25	..	19	6 00	83	..
10 23	..	27	2 29	60	..	6 01	77	..
10 29	77	..	2 39	60	19	6 14	69	20
10 31	86	..	2 56	62	19	6 25	70	18
10 41	..	25	3 04	63	19	6 40	83	23
10 44	71	..	3 13	64	..	6 43	75	..
10 54	..	23	3 14	68	..	6 44	70	..
10 58	82	23	3 27	62	20	6 57	73	21
11 27	63	21	3 40	..	18			

PULSE AND RESPIRATION—Continued.
Metabolism experiment No. 83.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Dec. 4			Dec. 5			Dec. 6		
P. M.			P. M.			P. M.		
$10^h 19^m$	69	21	$6^h 36^m$	61	18	$1^h 31^m$	77	18
10 44	59	19	6 49	74	17	1 40	56	..
10 54	68	..	7 04	..	18	1 53	54	16
11 27	80	19	7 20	82	..	2 00	71	..
11 43	77	20	7 43	79	18	2 13	73	17
Dec. 5			8 12	85	18	2 32	77	18
A. M.			8 39	76	18	2 49	75	18
$12^h 04^m$	67	18	9 05	56	17	3 13	80	21
12 20	72	20	9 15	83	..	3 24	99	19
12 39	64	18	9 23	..	19	3 33	92	..
12 49	65	17	9 43	74	18	3 46	89	21
1 07	65	17	10 04	..	19	3 56	..	20
1 28	65	16	10 11	78	..	4 16	87	21
2 05	63	16	10 32	70	16	4 30	81	21
2 24	..	18	10 48	74	18	4 47	83	..
2 54	63	17	11 17	76	20	5 06	83	18
3 11	63	16	11 31	..	18	5 24	..	20
3 35	63	16	11 52	..	17	5 39	82	18
3 53	66	17	Dec. 6			6 00	81	17
4 34	65	17	A. M.			6 12	80	..
4 55	65	..	$12^h 01^m$	59	..	6 25	73	16
5 40	67	16	12 32	..	17	6 30	72	..
5 53	64	18	12 57	73	16	6 44	69	18
6 04	..	18	1 25	63	16	7 31	71	21
6 17	63	17	1 52	63	16	7 55	66	17
6 39	..	17	2 10	66	15	8 15	81	22
7 30	..	21	2 37	63	16	8 35	71	21
8 23	..	19	2 53	67	17	9 07	..	19
8 42	56	19	3 16	72	18	9 38	75	18
9 04	..	22	3 52	69	17	9 49	76	19
9 26	84	16	4 19	58	17	10 04	69	17
9 52	..	21	4 35	69	17	10 28	62	16
10 11	72	21	5 05	66	16	10 57	63	15
10 36	85	..	5 27	70	17	11 15	75	18
10 43	..	17	6 09	71	18	11 48	75	19
10 53	70	18	6 39	72	18	Dec. 7		
11 17	75	23	6 48	71	17	A. M.		
11 48	..	21	6 54	76	19	$12^h 04^m$	73	16
P. M.			7 34	94	21	12 19	70	17
$12^h 27^m$	80	18	7 54	81	19	12 58	..	17
12 38	82	22	8 15	..	19	1 03	66	..
1 07	88	26	8 24	94	..	1 24	61	15
1 44	74	17	8 37	87	19	1 59	68	17
2 05	60	17	8 53	91	18	2 19	64	16
2 27	..	19	9 17	81	18	2 50	63	16
2 42	76	16	9 30	..	17	3 04	65	16
3 06	62	..	9 44	72	..	3 19	59	14
3 18	..	18	9 55	75	16	3 42	69	18
3 27	73	..	10 07	..	17	4 02	89	23
3 38	..	19	10 24	88	22	4 20	58	15
3 56	..	18	10 42	83	19	4 31	89	16
4 15	..	21	10 52	87	..	4 51	73	18
4 32	95	..	11 31	..	18	5 03	74	18
4 42	88	19	11 44	87	..	5 19	72	18
5 10	78	16	P. M.			5 32	72	19
5 23	..	16	$12^h 10^m$	..	21	5 47	74	18
5 33	81	17	12 20	87	..	6 23	72	20
6 10	73	17	12 33	82	23	6 40	77	20
6 18	78	..	12 42	..	20	6 55	75	19
6 27	..	18						

PULSE AND RESPIRATION—Continued.

Metabolism experiment No. 85.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Dec. 8			Dec. 9			Dec. 10		
P. M.			P. M.			A. M.		
$8^h 38^m$	62	13	$5^h 32^m$	46	..	$11^h 46^m$	67	14
8 48	63	13	5 47	57	14	P. M.		
9 04	62	..	5 56	..	12	$12^h 07^m$	..	12
9 20	64	..	6 14	59	..	12 16	..	13
9 56	..	14	6 23	..	14	12 31	58	..
10 13	53	..	6 44	..	12	12 39	71	..
10 45	48	12	7 27	62	..	12 43	..	13
11 15	..	13	7 47	..	11	12 54	67	13
11 52	..	12	7 54	61	..	2 06	67	..
Dec. 9			8 34	..	12	2 19	..	14
A. M.			8 49	63	..	2 27	..	14
$12^h 07^m$	57	..	8 54	..	12	2 35	51	..
12 23	..	14	9 23	48	14	2 45	..	14
1 21	..	11	9 37	54	14	3 17	59	14
1 50	46	..	10 03	..	13	3 29	59	13
2 12	..	11	10 22	51	..	3 45	63	13
2 29	45	12	10 31	..	12	4 37	62	..
3 23	..	11	10 43	59	..	5 29	69	13
4 08	..	11	11 39	..	11	5 38	..	13
4 23	56	..	11 43	..	11	6 07	69	..
5 08	..	12	11 51	..	11	6 15	71	..
5 22	44	..	Dec. 10			6 32	..	16
5 31	..	12	A. M.			7 07	..	13
6 09	60	12	$12^h 32^m$	..	12	7 15	75	13
6 26	57	13	12 45	66	..	7 30	94	15
6 48	54	11	1 15	..	12	7 50	79	..
8 24	71	13	1 24	56	..	7 59	..	16
8 34	62	..	1 43	..	12	8 13	77	14
8 46	..	12	2 17	50	11	8 37	68	17
8 53	59	11	2 39	..	12	9 16	73	13
9 32	68	13	2 54	67	11	9 33	80	16
9 48	67	15	3 05	69	14	10 14	..	14
10 07	62	16	3 29	57	11	10 30	65	16
10 23	57	..	3 50	66	..	10 45	65	..
10 43	..	12	4 16	52	12	11 11	73	15
10 50	61	13	4 34	..	13	11 30	..	15
11 15	..	13	4 55	..	12	11 45	73	..
11 29	51	12	5 03	64	12	Dec. 11		
11 50	..	10	5 26	69	..	A. M.		
P. M.			5 51	..	14	$12^h 02^m$	64	..
$12^h 08^m$	64	..	6 10	63	13	12 23	63	..
12 29	56	12	6 31	69	13	12 45	..	14
12 38	61	10	7 30	77	..	1 22	..	14
12 48	..	12	8 23	..	14	1 41	74	16
12 59	65	..	8 32	83	14	1 55	..	15
1 34	54	13	8 43	78	..	2 03	56	16
1 50	54	..	9 11	75	..	2 50	79	..
2 07	64	..	9 30	..	18	2 59	..	13
2 20	..	11	9 43	..	13	3 11	80	15
2 50	51	..	10 20	60	13	3 56	83	16
3 37	56	12	10 28	61	..	4 40	82	14
4 10	52	..	10 39	..	13	5 11	73	14
4 37	55	12	10 45	73	..	5 36	73	16
4 46	58	12	10 55	..	13	6 17	79	15
5 24	..	9	11 27	70	..	6 41	84	14

PULSE AND RESPIRATION—Continued.

Metabolism experiment No. 89.

Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.	Time.	Pulse per minute.	Respiration per minute.
Jan. 9			Jan. 10			Jan. 11		
P. M.			P. M.			P. M.		
$10^h 51^m$	..	19	$10^h 46^m$	67	..	$3^h 14^m$	59	..
11 34	50	..	11 02	46	..	3 28	..	16
11 51	..	17	11 18	..	19	3 44	59	17
Jan. 10			11 30	48	..	4 18	52	16
A. M.			Jan. 11			4 39	54	15
$1^h 14^m$	52	..	A. M.			4 53	..	16
1 34	..	18	$12^h 25^m$	..	15	5 50	..	18
2 06	51	..	12 47	50	..	6 30	..	22
2 48	..	13	1 15	..	17	6 50	..	19
4 19	44	..	1 46	50	..	7 11	77	21
4 40	..	11	2 24	54	16	7 19	75	20
5 31	..	14	2 55	50	..	7 35	..	23
6 15	..	15	3 15	..	17	7 46	..	22
6 48	47	..	3 34	48	..	8 09	..	21
6 59	..	16	4 23	51	..	8 19	63	20
7 30	..	17	4 34	..	15	8 34	..	20
7 42	71	..	5 38	..	17	8 44	58	..
8 16	64	..	6 15	46	..	8 49	62	18
8 35	..	20	6 31	..	14	9 08	55	19
8 54	63	..	6 47	54	..	9 30	..	20
9 49	59	17	7 27	63	..	9 39	53	..
10 09	64	16	7 38	..	16	10 19	61	19
10 35	..	13	8 08	66	..	10 38	..	24
11 07	65	..	8 24	69	19	11 06	..	22
11 44	47	..	8 46	57	..	11 22	..	19
P. M.			9 28	51	14	Jan 12		
$12^h 16^m$	48	..	10 46	47	16	A M.		
12 44	51	..	10 54	..	15	$12^h 25^m$	..	16
1 51	62	..	11 11	..	17	1 10	50	..
2 08	66	..	11 23	..	15	1 19	50	..
2 53	..	22	11 31	62	..	1 42	..	16
3 19	78	..	11 53	60	..	3 26	..	16
3 49	..	18	P. M.			3 38	49	..
4 21	47	17	$12^h 17^m$	..	17	5 13	..	15
6 54	..	20	12 30	55	..	5 29	46	..
7 19	..	20	12 48	62	16	5 38	50	..
7 35	59	..	2 05	67	21	6 10	..	16
7 59	75	..	2 26	68	..	6 23	54	..
8 56	51	18	2 35	..	20	6 38	..	16
9 59	55	19	2 46	61	..	6 48	49	..
10 34	..	22						

Record of body movements.—The subjects of these 2-day experiments followed no very definite routine, except that the times of rising, weighing, and retiring were the same for all. Their activity varied with their temperament and inclinations though in no case was there evidence of much muscular exertion, and all the experiments were essentially "rest experiments." An index of the muscular activity of the different men may be obtained from the "movements of subjects" recorded below.

The men were all cautioned to attempt to secure like muscular activity on the 2 days of the experiments. In some instances this was accomplished by having the record of body movements for the first 24 hours prepared during the night and requiring that the subject duplicate this record as nearly as possible on the second day.

MOVEMENTS OF SUBJECTS.

Experiment No. 79, H. E. S., Oct. 13, 7 a. m., to Oct. 15, 7 a. m., 1905.

	October 13.
A. M.	
$7^h\ 02^m$	rise, dress.
7 06	weigh self, etc.
7 13	
7 20	sit, write.
7 24	telephone.
7 29	food aperture.
7 40	drink, write.
7 42	lie, read.
7 52	move about, food aperture.
7 54	read.
8 28	telephone.
8 32	sit, food aperture, rise.
8 33	urinate.
8 34	sit, drink.
8 36	write.
8 38	lie, read.
8 40	telephone, read.
9 08	rise, strength test.
9 12	telephone, strength test.
9 18	write.
9 20	lie, read.
9 36	write.
9 45	drink.
9 52	telephone, read.
10 07	drink.
10 24	sit, telephone.
10 26	rise, food aperture.
10 28	sit, rise, sit.
10 30	lie, read.
10 36	urinate.
11 18	telephone.
11 22	rise, food aperture.
11 24	sit, drink, food aperture.
11 26	rise, lie, read.
A. M.	
$11^h\ 35^m$	write.
11 54	telephone.
11 56	sit, food aperture.
11 58	rise.
P. M.	
$12^h\ 02^m$	raise table, sit, write.
12 07	urinate.
12 24	telephone, write.
1 04	read, seal letter.
1 08	stand, telephone.
1 12	drink.
1 14	write.
1 16	food aperture, read.
1 20	stand, read.
1 22	sharpen pencil.
1 26	read.
2 10	rise.
2 12	food aperture, telephone.
2 14	open bed.
2 16	stand, write.
2 18	lie, read.
2 24	sit, food aperture.
2 25	lie, read.
2 34	sit, food aperture.
2 36	telephone.
2 38	lie.
4 04	rise, urinate, sit, write.
4 08	telephone.
4 20	comb hair.
4 28	read.
5 02	write.
5 04	rise, urinate.
5 08	lie, read.
5 12	sit, food aperture.
5 14	lie, read.
P. M.	
$5^h\ 44^m$	telephone.
7 04	rise, urinate.
7 06	telephone, sit.
7 08	food aperture.
7 10	sit.
7 16	lie, read.
8 02	telephone.
8 05	food aperture.
9 02	rise, urinate.
9 04	lie.
10 02	sit, write.
10 08	rise, coat off.
10 10	lie.
10 12	asleep.
11 02	rise, urinate, write.
11 04	close curtain, undress, retire.
	October 14.
A. M.	
$2^h\ 24^m$	rise.
7 02	rise, dress, urinate.
7 14	weigh self, etc.
7 18	
7 22	food aperture.
7 24	telephone.
7 25	food aperture.
8 14	sleep.
8 28	telephone.
8 30	lie.
8 34	asleep.
9 02	telephone.
9 04	rise.
9 06	strength test.
9 08	sit, write.
9 14	food aperture.
9 18	telephone.
9 24	food aperture.
9 25	urinate.

MOVEMENTS OF SUBJECTS.—Continued.

October 14 (cont.)

A. M.	
9h 28m	lie, study.
9 52	telephone.
9 54	sit, food aperture.
9 58	rise, move about.
10 00	lie, read.
10 18	telephone.
10 20	sit, food aperture.
11 24	lie.
11 36	sit, food aperture.
P. M.	
12h 08m	sit, read.
12 36	read.
12 38	sit erect.
1 02	telephone.
1 04	food aperture.
1 08	read.
P. M.	
1h 10m	write.
1 12	drink.
1 14	look at watch, lie.
1 24	telephone, lie.
1 34	read.
2 20	sit.
2 25	lie, read.
3 02	asleep.
3 12	sit, food aperture.
3 14	lie.
3 24	read.
3 46	doze.
3 50	count pulse.
4 40	doze.
5 02	sit, urinate, telephone.
5 06	food aperture.
P. M.	
5h 08m	lie, read.
5 28	stop reading.
5 52	read.
6 08	stop reading.
7 02	rise, urinate.
7 06	sit, write.
7 08	food aperture.
7 10	drink, write.
7 18	lie.
7 40	restless.
8 06	strength test.
8 10	open bed, write.
8 12	drink, lie.
8 24	doze.
11 02	rise, urinate.
11 04	undress, close curtain, retire.

Experiment No. 80, O. R. Y., Oct. 27, 7 a. m., to Oct. 29, 7 a. m., 1905.

October 27.

A. M.	
7h 00m	rise, urinate.
7 06 } 7 14 }	weigh self, etc.
7 26	dress, sit.
7 33	food aperture.
7 34	wipe absorbers.
7 54	food aperture.
9 02	telephone.
9 08	stand, strength test.
9 06	sit, read.
9 26	telephone.
9 30	read.
10 08	telephone.
10 10	rise, food aperture.
10 14	sit.
10 38	read.
P. M.	
12h 20m	rise, open bed, urinate.
12 22	arrange bed, lie, read.
1 04	sit, telephone.
1 44	stop reading, recline.
2 02	asleep.
4 06	sit, telephone, food aperture.
4 08	rise, strength test.
4 10	read.
4 40	lie.
5 22	doze.
P. M.	
7h 06m	rise, telephone.
7 08	urinate, lie.
11 00	rise, urinate.
11 02	arrange bed.
11 04	strength test.
11 10	close curtain, undress, retire.
11 18	telephone, food aperture, drink.

October 28.

A. M.	
7h 00m	rise, urinate.
7 05 } 7 10 }	weigh self, etc.
7 20	drink.
7 40	sit.
8 08	write.
8 16	count pulse.
8 36	asleep.
8 42	awake.
9 04	rise, strength test.
9 08	rise, food aperture.
9 10	sit.
9 18	asleep.
9 48	awake.
9 54	asleep.
10 02	telephone, rise, sit.
10 34	asleep.
11 04	telephone.
11 08	rise, food aperture.
11 12	sit.
11 14	elbow on knee.
A. M.	
11h 20m	move.
11 22	arrange bed, lie.
11 34	asleep.
P. M.	
12h 32m	asleep.
1 00	awake, telephone.
1 02	read.
1 04	urinate.
1 06	sit, food aperture.
1 08	lie.
1 24	asleep.
2 08	awake, turn over, asleep.
3 04	awake.
3 10	restless.
3 26	doze.
3 34	awake.
5 04	sit, telephone.
5 06	strength test, sit, telephone.
5 12	lie.
6 20	sit, telephone.
7 02	rise, urinate.
7 06	sit, take temperature.
7 08	lie.
8 00	asleep.
11 00	awake, rise, urinate.
11 04	strength test.
11 07	food aperture.
11 12	close curtain.
11 20	drink, retire.

MOVEMENTS OF SUBJECTS.—Continued.

Experiment No. 81, A. H. M., Nov. 21, 7 a. m., to Nov. 23, 7 a. m., 1905.

November 21.

A. M.
7h 02m rise, telephone, open curtain.
7 04 urinate, dress.
7 06 telephone.
7 08 } weigh self, etc.
7 18 }
7 22 sit, write.
7 24 food aperture, sit, drink.
7 42 read.
8 34 stop reading.
8 42 read.
9 02 rise, food aperture.
9 04 strength test.
9 06 telephone.
9 10 sit, read.
9 24 rise, food aperture.
9 30 stand, read.
9 40 sit, read.
11 02 rise, move about.
11 04 sit.
11 08 read.
11 26 turn around.
11 28 read.
11 44 move chair.
P. M.
12h 08m read.
1 02 telephone.
1 04 rise, food aperture, urinate, stand.
1 12 stand.
1 14 sit.
1 24 arrange clothes, sit.
1 28 sit, chair tilted.
2 14 asleep.
2 16 sit.
2 22 read.
3 02 telephone, rise, strength test.
3 04 telephone.
3 06 sit.
3 10 rise, food aperture.
3 12 sit, read.
3 40 read.
4 02 rise, sit, wave arms.
4 24 telephone.
P. M.
4h 26m stand, adjust thermometer.
4 28 move about, sit.
4 32 read, elbow on knees.
5 02 stand.
5 04 telephone.
5 06 sit, read.
5 14 rise, food aperture.
5 16 sit.
5 20 stand, sit.
5 32 stand.
5 34 sit, read.
6 04 read.
7 00 telephone.
7 02 food aperture, urinate.
7 06 telephone, stand, food aperture.
7 10 sit.
7 20 read.
7 54 stop reading.
8 10 read.
8 50 stop reading.
9 04 stand, strength test.
9 08 sit.
9 48 read.
10 20 stop reading.
10 26 read.
11 00 telephone.
11 02 rise, urinate, open bed.
11 04 close curtain, undress, retire.

November 22.

A. M.
7h 02m telephone, rise, open curtain.
7 06 urinate, dress, fold bed.
7 08 } weigh self, etc.
7 19 }
7 20 adjust chair, sit, telephone.
7 26 food aperture.
7 28 stand, adjust thermometer.
7 30 sit.
7 45 drink, write.
A. M.
8h 24m telephone.
8 32 read, write.
8 40 read.
9 02 telephone, rise, food aperture.
9 04 sit, rise, strength test.
9 08 sit, telephone.
9 12 elbows on knees.
9 40 telephone, adjust thermometer.
10 16 food aperture.
10 20 write.
P. M.
12h 08m telephone, move about.
12 10 adjust thermometer, sit.
12 28 read.
12 46 rest, elbows on knees.
1 02 rise, urinate.
1 04 write.
1 06 telephone.
1 08 arrange bed, lie.
1 44 asleep.
2 16 sit, arrange blanket, lie.
4 48 awake.
5 02 telephone.
5 04 read.
6 08 sit, read.
6 12 rise.
6 14 urinate.
6 16 sit, read.
7 02 rise, urinate.
7 04 strength test.
7 06 telephone.
7 08 food aperture.
7 12 sit, read.
7 32 lie.
7 44 asleep.
8 20 read.
9 02 stop reading.
10 08 read.
10 24 telephone.
11 02 rise, urinate.
11 04 open bed, undress, close curtain, retire.

Experiment No. 82, H. C. K., Nov. 24, 7 a. m., to Nov. 26, 7 a. m., 1905.

November 24.

A. M.
7h 02m rise, urinate, fold bed, dress.
7 09 } weigh self, etc.
7 17 }
7 22 telephone.
A. M.
7h 23m food aperture.
7 24 move about, adjust pneumograph and thermometer.
7 28 sit, write.
A. M.
7h 30m write.
7 35 adjust table.
8 04 sit, read.
8 42 stop reading.
9 04 telephone.
9 06 rise, food aperture.

MOVEMENTS OF SUBJECTS.—Continued.

November 24 (cont.)

A. M.

$9^{h}\,08^{m}$ sit.
9 12 telephone.
9 14 rise, strength test.
9 16 sit, write.
9 36 telephone.
9 38 rise, food aperture, sit.
9 40 sit.
9 42 write.
11 12 telephone, rise, sit.
11 16 write.

P. M.

$1^{h}\,04^{m}$ telephone.
1 06 sit.
1 10 rise, urinate, food aperture, drink.
1 14 telephone.
1 16 remove thermometer.
1 18 food aperture.
1 22 sit, write.
1 24 food aperture.
1 26 sit, adjust thermometer.
1 30 sit, write.
1 48 sit, read, write.
3 04 telephone, rise, food aperture, sit.
3 06 rise, food aperture, drink.
3 08 sit, telephone.
3 10 strength test.
3 14 sit.
3 16 lower table, open bed.
3 18 write.
3 20 lie.
3 26 asleep.
5 30 sit, drink, lie.
7 02 rise, telephone.
7 04 food aperture.
7 06 urinate.

P. M.

$7^{h}\,12^{m}$ fold bed, brush mercury from floor.
7 15 raise table.
7 22 sit, write.
7 30 study.
9 05 drink.
9 55 strength test.
10 25 drink.
10 30 sit, study.
11 02 rise, urinate, drink.
11 04 open bed.
11 08 undress, retire.

November 25.

A. M.

$7^{h}\,02^{m}$ rise, urinate.
7 04–7 15 dress, weigh self, etc.
7 20 sit, write.
7 26 food aperture.
7 32 close curtain, defecate.
7 42 adjust thermometer, connect respiration tube.
7 42 sit, raise table.
7 48 food aperture.
7 50 drink.
7 54 write.
8 00 sit.
8 10 food aperture.
8 20 read.
8 30 write.
9 02 telephone.
9 04 food aperture.
9 06 move, sit.
9 10 write.
9 14 sit.
9 48 telephone.
10 02 head on arms on table.
10 06 doze.
10 22 sit.

A. M.

$10^{h}\,26^{m}$ telephone.
10 30 study.
11 02 telephone, rise.
11 04 strength test.
11 14 food aperture.
11 20 play cards.

P. M.

$1^{h}\,00^{m}$ telephone, urinate, drink.
1 02 move, sit, play cards.
1 28 sit.
2 10 doze.
2 32 write.
2 34 play cards.
3 04 drink.
3 10 write.
3 38 rest, strength test.
3 40 food aperture, sit.
3 44 write.
3 46 fold table, open bed.
3 50 lie.
3 52 sit, telephone, food aperture, drink.
4 04 doze.
7 04 rise, urinate, drink.
7 06 telephone.
7 12 sit, write.
7 16 telephone.
7 20 food aperture, read.
7 30 fold bed, raise table, sit, write.
8 15 drink.
8 20 play cards.
9 25 food aperture, drink.
9 26 strength test.
9 28 sit, play cards.
11 05 rise, urinate, drink.
11 06 fold table, open bed.
11 12 close curtain, retire.

Experiment No. 83, H. R. D., Dec. 5, 7 a. m., to Dec. 7, 7 a. m., 1905.

December 5.

A. M.

$7^{h}\,00^{m}$ rise.
7 02 open curtain, urinate.
7 04 dress.
7 06–7 22 fold bed, weigh self, etc.
7 28 sit, write.
7 40 read, write.
8 08 telephone.

A. M.

$8^{h}\,12^{m}$ rise, food aperture, drink.
8 16 sit.
8 18 write.
8 38 read.
9 00 urinate.
9 04 telephone.
9 08 rise, food aperture.
9 13 rise, food aperture.
9 14 sit.

A. M.

$9^{h}\,16^{m}$ rise, open bed, lie.
9 44 sit, telephone.
9 46 rise, food aperture.
9 48 lie, sit, telephone.
9 50 rise, food aperture, sit.
9 56 food aperture.
9 58 lie.
10 22 doze.
11 02 sit, telephone.

MOVEMENTS OF SUBJECTS.—Continued.

December 5 (cont.)

A. M.	
$11^{h}\ 04^{m}$	rise, strength test.
11 06	fold bed.
11 08	urinate, drink.
11 10	raise table, sit, write.
P. M.	
$12^{h}\ 05^{m}$	urinate.
12 20	telephone.
12 24	write.
12 44	stop writing, sit.
1 00	urinate.
1 02	telephone, read.
1 06	write.
1 08	sit.
1 10	rise, open bed, lie.
1 12	asleep.
2 30	awake.
4 04	sit, food aperture.
4 08	raise table.
4 12	sit, write.
4 15	urinate.
4 18	sit.
4 20	rise, food aperture.
4 22	sit, drink.
4 24	write.
4 32	open bed, lie.
4 34	cover self with blanket.
5 06	asleep.
7 02	telephone.
7 04	urinate.
7 06	strength test.
7 12	sit, telephone.
7 14	food aperture, drink.
7 24	rise, move about.
7 26	fold bed.
7 30	sit, write, restless.
8 10	food aperture.

P. M.	
$8^{h}\ 15^{m}$	read.
9 10	drink.
9 25	urinate.
9 36	fold table, open bed, lie, asleep.
11 00	rise.
11 02	urinate, telephone.
11 04	open bed, undress, retire.

December 6.

A. M.	
$5^{h}\ 00^{m}$	rise, urinate, lie, asleep.
7 02	rise, urinate.
7 04	fold clothes, dress.
7 06	hang chair.
7 09 7 16	weigh self, etc.
7 18	telephone.
7 24	food aperture, drink.
7 26	raise table.
7 28	telephone.
7 32	sit, write.
7 34	food aperture.
7 38	sit, write.
8 15	drink, write.
9 02	rise, food aperture.
9 04	sit, write.
9 08	drink.
9 10	rise, fold table, open bed, lie.
9 12	cover self, asleep.
11 02	rise, strength test, urinate.
11 04	fold bed, raise table, sit.
11 12	drink.
11 20	write.

P. M.	
$12^{h}\ 28^{m}$	sit.
12 36	sit, write.
12 40	sit, feet on table.
1 02	urinate.
1 06	write, telephone.
1 08	fold table, sit.
1 10	lie, cover self.
1 14	asleep.
2 50	awake.
3 24	sit, lie.
3 30	food aperture.
4 08	rise, urinate, fold bed, raise table, write.
4 22	rise, food aperture.
4 25	sit, drink.
4 32	lie.
4 40	lean on elbow, lie.
5 22	asleep.
7 02	rise, raise table.
7 04	sit, urinate, drink, write.
7 16	strength test.
7 34	read.
7 44	write.
8 35	turn chair, lean on table.
9 02	fold table, open bed, lie, asleep.
11 02	rise, urinate.
11 04	open bed, undress, close curtain, retire.

December 7.

A. M.	
$5^{h}\ 30^{m}$	rise, urinate, lie, asleep.

Experiment No. 85, N. M. P., Dec. 9, 7 a. m., to Dec. 11, 7 a. m., 1905.

December 9.

A. M.	
$7^{h}\ 00^{m}$	rise.
7 02	telephone.
7 04	remove thermometer.
7 08	urinate.
7 10	dress, fold bed.
7 12 7 20	weigh self, etc., telephone.
7 22	telephone.
7 24	raise table.
7 26	food aperture.
7 30	adjust thermometer and pneumograph.
7 32	sit, write.

A. M.	
$7^{h}\ 36^{m}$	rise, sit.
7 40	drink.
7 44	stretch arms.
7 50	write.
8 28	sit.
8 34	write.
8 48	sit, arms over head.
9 06	telephone.
9 08	rise, food aperture.
9 10	sit, rise, strength test.
9 12	write.
9 15	drink.
9 26	sit.
9 30	write.

A. M.	
$9^{h}\ 50^{m}$	telephone.
9 52	rise, food aperture.
9 54	sit.
10 04	read.
10 24	turn chair, read.
10 28	telephone.
10 32	read.
10 52	stretch arms over head.
11 04	telephone.
11 12	telephone, food aperture.
11 14	sit, read.
11 26	study.
11 44	rise, move about.
11 48	sit.

MOVEMENTS OF SUBJECTS.—Continued.

December 9 (cont.)

P. M.	
$12^h 04^m$	sit erect.
12 06	read.
12 48	study.
1 00	telephone.
1 02	stand, urinate.
1 04	food aperture.
1 06	drink, sit, study.
1 14	rise.
1 16	write.
1 18	fold table, open bed.
1 20	lie, read.
1 46	telephone.
2 04	asleep.
2 08	turn over.
3 02	turn over.
3 08	rise, urinate, drink.
3 10	move about, lie, read.
3 38	sit, strength test.
3 40	telephone.
3 42	write.
3 50	lie, read.
4 40	stop reading.
5 00	turn over.
5 56	sit, lie.
7 02	sit.
7 03	food aperture.
7 06	move about.
7 08	close curtain, urinate.
7 10	open curtain.
7 12	move about.
7 16	sit.
7 24	stand.
7 26	sit.
7 28	stand.
7 32	telephone.
7 34	raise shield, sit, read.
7 38	raise table, sit, read.
9 06	strength test.
9 12	rise, open bed.
9 14	lie, read.
9 16	sit, read.
11 00	telephone.
11 02	undress.
P. M.	
$11^h 08^m$	urinate.
11 12	close curtain, retire.

December 10.

A. M.	
$7^h 00^m$	rise.
7 02	dress, urinate.
7 04 } 7 11 }	telephone, weigh self, etc.
7 12	telephone.
7 14	drink.
7 16	telephone.
7 17	food aperture.
7 22	sit.
7 24	adjust thermometer.
7 34	raise table.
7 36	sit, write.
7 40	telephone.
7 46	rise, remove thermometer.
7 48	food aperture.
7 50	sit.
7 54	rise, stand.
7 56	food aperture.
8 02	sit, write.
8 08	telephone.
8 10	rise, move about, food aperture.
8 12	sit, read.
8 32	read.
9 02	telephone, write.
9 08	rise, food aperture.
9 10	sit, take temperature.
9 16	rise, food aperture.
9 18	sit, telephone.
9 20	rise, move about.
9 24	rise, food aperture.
9 32	drink.
9 34	lie.
9 36	read.
9 46	telephone.
9 48	telephone.
9 50	sit, food aperture.
9 52	lie, telephone.
9 54	sit, food aperture.
9 56	clean food aperture.
P. M.	
$9^h 58^m$	lie.
10 08	telephone.
10 24	doze.
10 44	read.
11 02	telephone, sit, food aperture.
11 04	rise, sit, adjust thermometer.
11 10	sit, read.
11 16	telephone, sit.
11 20	read.
11 28	telephone.
11 34	strength test.
11 36	sit, read.
P. M.	
$1^h 02^m$	telephone, urinate.
1 09	food aperture.
1 10	sit.
1 12	write.
1 20	read.
1 38	telephone.
1 46	read.
2 20	rise, food aperture, move about.
2 24	lie.
2 44	doze.
2 56	read.
3 18	doze.
4 02	telephone.
4 04	sit, strength test.
4 08	lie, read.
7 00	urinate.
7 04	telephone, food aperture.
7 06	sit, read.
7 14	rise, sit.
7 28	telephone.
7 42	telephone.
7 44	food aperture.
9 20	strength test.
9 24	sit.
9 26	write.
10 18	fold table.
10 20	lie.
10 22	move about.
10 30	lie.
11 04	urinate.
11 06	undress.
11 08	close curtain, retire.

Experiment No. 89, D. W., Jan. 10, 7 a. m., to Jan. 12, 7 a. m., 1906.

January 10.

A. M.	
$7^h 00^m$	rise, fold bed.
7 04	urinate, adjust chair.
7 06	dress, telephone.
A. M.	
$7^h 07^m$	urinate.
7 08 } 7 15 }	weigh self, etc.
7 16	adjust chair, telephone.
A. M.	
$7^h 20^m$	arrange bed, adjust table, sit, write.
7 26	read.
7 52	telephone.

MOVEMENTS OF SUBJECTS.—Continued.

January 10 (cont.)

A. M.	
7^h 54^m	rise, remove thermometer
7 56	food aperture.
8 02	sit, read.
8 40	stop reading, play cards.
9 08	telephone.
9 10	food aperture.
9 12	open bed, lie.
10 48	turn over.
P. M.	
12^h 22^m	awake.
12 30	read.
12 50	sit, telephone.
12 52	lie, read.
1 00	urinate.
1 04	sit.
1 06	adjust thermometer, write.
1 08	move about.
1 12	read.
1 36	telephone.
1 38	strength test.
1 44	sit, write.
1 46	read.
2 48	write.
2 50	play cards.
3 02	telephone.
3 06	rise, food aperture.
3 08	lie, sit.
5 04	awake.
5 26	rise, fold bed, adjust table, sit, write.
6 08	read.
7 02	urinate.
7 06	telephone.
8 00	strength test.
8 10	lie, read.
8 56	turn over.
9 40	telephone.
9 42	stop reading, play cards.
9 46	food aperture.
9 48	sit, play cards.
10 00	stand, strength test.
10 08	sit, play cards.
10 26	stop playing.

P. M.	
10^h 28^m	arrange pneumograph, food aperture.
10 30	write.
10 42	stop writing.
10 50	sit erect.
11 02	telephone, close table, urinate.
11 04	undress, open bed.
11 06	retire.

January 11.

A. M.	
3^h 50^m	wake, rise, arrange pneumograph.
3 52	sit, write.
3 56	food aperture, drink.
3 58	retire.
7 00	rise, fold clothes.
7 04	adjust chair.
7 06 7 11	weigh self, etc.
7 12	food aperture, telephone.
7 14	urinate.
7 16	adjust table, telephone.
7 18	food aperture.
7 20	sit, write.
8 00	drink.
8 30	sit erect.
8 32	read.
9 02	telephone.
9 04	rise, food aperture.
9 06	open bed.
9 08 11 00	lie, asleep, awake, asleep.
P. M.	
12^h 06^m	awake.
1 02	telephone.
1 04	urinate.
1 06	move about.
1 08	drink, sit, write.
1 10	rise, food aperture, drink.
1 12	sit.
1 28	write.
1 42	strength test.
1 46	write.
1 56	rise, food aperture.
2 02	sit, read.

P. M.	
3^h 02^m	fold table, open bed.
3 04	lie, asleep.
5 00	awake.
5 24	fold bed, adjust table.
5 26	sit, write.
5 30	food aperture.
5 32	sit, mend bed, drink.
5 34	sit, write.
5 41	food aperture.
6 02	play cards.
6 52	telephone.
7 02	urinate.
7 04	food aperture.
7 06	telephone.
7 08	food aperture.
7 10	read.
7 14	stop reading, drink, write.
7 30	telephone.
8 00	stop writing.
8 02	strength test.
8 06	sit, write.
8 10	stop writing, drink.
8 12	remove table, arrange bed, lie.
9 14	rise, adjust table, write.
9 16	write.
9 17	drink, read.
9 44	stop reading, write.
10 10	stop writing, stand.
10 12	strength test.
10 14	sit, write.
10 20	telephone, food aperture.
10 22	play cards, food aperture, drink.
10 24	play cards.
10 42	stop playing.
10 46	sit quietly.
11 04	drink, telephone, urinate, undress.
11 06	remove table, arrange bed, close curtain, retire.

Drinking-water.—As in the earlier experiments the subjects were allowed drinking-water whenever desired with no restriction as to the amounts. The quantities consumed were not accurately measured except for each 24 hours, but the estimated amounts per period recorded in table 162 are probably not far from correct.

An examination of table 162 shows wide variation in the daily intake of water for the different experiments. The minimum amount consumed during 24 hours by any subject was 115.1 grams, and the maximum was 1467.1 grams. In general these subjects drank less water than the 3 men who were the subjects of experiments Nos. 59 and 68 to 77. Water from the city supply was used and no allowance was made for the small amounts of organic matter and salts which it contained.

TABLE 162.—*Record of water consumed—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	7 to 9 a. m.	9 to 11 a. m.	11 a. m. to 1 p. m.	1 to 3 p. m.	3 to 5 p. m.	5 to 7 p. m.	7 to 9 p. m.	9 to 11 p. m.	11 p. m. to 1 a. m.	Total for day.
Experiment No. 79, H. E. S.:	*Gms.*	*Gms.*	*Gms*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Oct. 13-14, 1905	224.8	224.8	69.3	161.1	....	....	102.5	....	....	782.5
Oct. 14-15, 1905	147.5	....	....	38.4	....	....	154.0	....	....	339.9
Experiment No. 80, C. R. Y.:										
Oct. 27-28, 1905	....	....	....	....	....	....	....	....	[1] 182.8	182.8
Oct. 28-29, 1905	[1] 63.3	....	....	....	....	....	....	....	[1] 143.1	206.4
Experiment No. 81, A. H. M.:										
Nov. 21-22, 1905	146.1	....	....	....	....	40.9	104.1	....	....	291.1
Nov. 22-23, 1905	124.3	....	....	....	....	....	69.5	....	....	193.8
Experiment No. 82, H. C. K.:										
Nov. 24-25, 1905	103.1	....	....	104.5	104.5	104.6	....	295.8	145.3	857.8
Nov. 25-26, 1905	148.0	....	....	148.0	294.3	....	292.7	105.0	104.9	1092.9
Experiment No. 83, H. R. D.:										
Dec. 5-6, 1905	448.4	....	219.6	219.5	154.0	....	212.8	212.8	....	1467.1
Dec. 6-7, 1905	147.2	147.2	147.2	....	221.3	....	221.3	....	....	884.2
Experiment No. 85, N. M. P.:										
Dec. 9-10, 1905	125.7	125.6	....	140.2	140.1	....	86.5	86.4	....	704.5
Dec. 10-11, 1905	288.6	183.6	....	....	64.4	....	85.5	85.6	....	707.7
Experiment No. 89, D. W.:										
Jan. 10-11, 1906	[2] 115.1	....	....	....	....	....	....	...	....	115.1
Jan. 11-12, 1906	48.8	....	....	89.2	....	89.1	78.0	115.1	42.0	857.2

[1] Amounts known. In other experiments one or more of the amounts per period are estimated.
[2] 3 to 5 a. m.

URINE.

The urine was collected daily at 7 a. m., 1 p. m., 7 p. m., and 11 p. m. Unfortunately the subject of experiment No. 79 did not collect the urine on the first morning until an hour and a half after the experiment began. It was impossible to make any satisfactory allowance for the excess included in the preliminary urine and no attempt has been made to correct for it. The error would probably be proportional to the time of the experiment and hence from 6 to 10 per cent would represent the error. During experiment No. 85, a small quantity of the urine for the second period of December 9 was spilled in the food aperture and on the floor of the chamber. This was immediately taken up with cheese cloth, and the nitrogen content determined and added to the total nitrogen for the day. The total weight of the urine

spilled was obtained by the ratio of its nitrogen content to the nitrogen of the measured urine. The same method was employed in calculating the carbon, hydrogen, ash, and solid matter in the urine spilled. While it is impossible that all the urine was taken up by the cheese cloth, it is believed that the error introduced is inappreciable.

As stated above, the amount of urine was obtained for each period in all experiments. The specific gravity of the urine for the different periods, however, was not taken, except during the first day of experiment No. 79, and the

TABLE 163.—*Amounts and specific gravity of urine—Metabolism experiments Nos. 79-83, and 85.*

Experiment number, subject, and date.	$8^h 33^m$ a. m. to 1 p. m.	7 a. m. to 1 p. m.	1 to 7 p. m.	7 to 11 p. m.	11 p. m. to 7 a. m.	Total for day.	Specific gravity.
Experiment No. 79, H. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
Oct. 13–14, 1905	[1] 591.4	....	[2] 171.5	[3] 76.7	[4] 187.6	1027.2	1.0118
Oct. 14–15, 1905	....	214.5	186.6	132.4	325.6	859.1	1.0223
Experiment No. 80, C. R. Y.:							
Oct. 27–28, 1905	....	186.2	210.4	180.9	569.9	1147.4	1.0169
Oct. 28–29, 1905	....	254.2	168.7	111.0	243.5	777.4	1.0237
Experiment No. 81, A. H. M.:							
Nov. 21–22, 1905	....	199.4	133.5	82.9	244.2	660.0	1.0264
Nov. 22–23, 1905	....	191.4	213.4	138.9	287.5	831.2	1.0230
Experiment No. 82, H. C. K.:							
Nov. 24–25, 1905	....	193.3	124.5	62.6	195.3	575.7	1.0261
Nov. 25–26, 1905	....	161.3	343.7	931.9	358.1	1795.0	1.0127
Experiment No. 83, H. R. D.:							
Dec. 5–6, 1905	....	558.2	246.5	124.4	275.4	1204.5	1.0146
Dec. 6–7, 1905	....	335.5	306.2	159.7	263.6	1065.0	1.0186
Experiment No. 85, N. M. P.:							
Dec. 9–10, 1905	....	332.7	618.3 [5] 34.6	106.0	131.0	1222.6	1.0154
Dec. 10–11, 1905	....	192.3	267.2	80.3	139.6	679.4	1.0203

[1] Specific gravity, 1.0057.
[2] Specific gravity, 1.0169.
[3] Specific gravity, 1.0220.
[4] Specific gravity, 1.0238.
[5] Calculated as spilled. This is included in the total for the day. See p. 243.

2 days of experiment No. 89. Except in the latter experiment, determinations of nitrogen and other constituents of the urine were made only on the daily composites. The amounts of urine by periods and the specific gravity for each day are given in table 163. The corresponding data for experiment No. 89 are given in a separate table, for the reason that in this experiment the nitrogen was determined on the urine for each period.

Weight and composition of urine.—In table 165 are recorded the determinations of elements and compounds in the urine for each day of the series, together with the heat of combustion of the organic matter of each daily sample. In considering the table, special attention should be paid to the note on experiment No. 85.

ELIMINATION OF WATER-VAPOR.

The total water of respiration and perspiration eliminated per period and per day and the total amount of water-vapor remaining in the calorimeter chamber at the end of each period are shown in table 166. In the notes at the foot of the table are shown the changes in weight of the chair, bed, bedding, etc., in the chamber. The object of recording these data has already been explained. (See p. 30.)

ELIMINATION OF CARBON DIOXIDE AND ABSORPTION OF OXYGEN.

Table 167 records the total weights of carbon dioxide exhaled and of oxygen consumed. The method of obtaining the data has been previously explained.

TABLE 164.—*Determinations in urine per period and per day—Metabolism experiment No. 89.*

Date.	Period.	(a) Amount.	(b) Specific gravity.	(c) Volume (a÷b).	(d) Nitrogen.
1906.		*Grams.*		*c. c.*	*Grams.*
Jan. 10–11...	7 a.m. to 1 p.m.	225.2	1.0264	219	2.82
	1 p.m. 7 p.m.	200.6	1.0280	195	2.73
	7 p.m. 11 p.m.	84.3	1.0303	82	1.49
	11 p.m. 7 a.m.	134.3	1.0326	130	2.95
	Total.	644.4	....	626	9.99
	Total by composite	644.4	1.0296	626	10.47
Jan. 11–12...	7 a.m. to 1 p.m.	126.5	1.0319	123	3.18
	1 p.m. 7 p.m.	142.5	1.0340	138	3.69
	7 p.m. 11 p.m.	91.4	1.0329	88	2.54
	11 p.m. 7 a.m.	179.2	1.0318	173	5.05
	Total	539.6	....	522	14.46
	Total by composite	539.6	1.0338	522	14.43
	Total for 2 days	1184.0	....	1148	24.45

Since the measurement of these gases during the preliminary night furnishes a part of the data regarding the transition from the katabolism with food to katabolism during inanition, the amounts for the preliminary period have been included whenever possible.

ELEMENTS KATABOLIZED IN THE BODY.

The elements katabolized in the body during each of the experiments are recorded in table 168. The usual method of computation was followed in obtaining the data. Preparatory to substitution in the formulæ used in computing the materials katabolized, the results have been carried to the second decimal[a] place.

[a] See discussion of the use of significant figures, p. 17.

TABLE 165.—*Weight, composition, and heat of combustion of urine—Metabolism experiments Nos. 79-83, 85, and 89.*

	Experiment No. 79. H. E. S.		Experiment No. 80. C. R. Y.	
	Oct. 13-14, 1905.	Oct. 14-15, 1905.	Oct. 27-28, 1905.	Oct. 28-29, 1905.
(a) Weight........grams..	1027.2	859.1	1147.4	777.4
(b) Water........do....	996.08	809.96	1105.75	734.80
(c) Solids, a—b........do....	31.12	49.14	41.65	42.60
(d) Ash........do....	8.73	11.17	18.93	12.52
(e) Organic matter, c—d........do....	22.39	37.97	22.72	30.08
(f) Nitrogen........do....	8.11	14.35	7.78	9.95
(g) Carbon........do....	6.27	10.22	7.11	9.02
(h) Hydrogen in organic matter....do....	1.75	3.09	2.07	2.57
(i) Oxygen (by difference) in organic matter, e—(f+g+h)........grams..	6.26	10.31	5.76	8.54
(j) Phosphorus........do....	.472	.726	.517	1.057
Phosphoric acid (P_2O_5):				
(k) by fusion........grams..	1.081	1.664	1.184	2.421
(l) by titration........do	1.124	1.765	1.267	2.754
(m) Sulphur........do....	.543	.777	.389	.685
Sulphur trioxide (SO_3):				
(n) Total........grams..	1.355	1.940	.969	1.711
(o) Inorganic and ethereal........do....	1.162	1.701	.827	1.483
(p) Neutral, n—o........do....	.193	.239	.142	.227
(q) Creatine (preformed)........do....	1.212	1.254	1.505	1.398
(r) Total creatinine........do....	1.225	1.418	1.505	1.538
(s) Creatinine[1] (preformed), r—q ...do....	.013	.164	.....	.140
(t) Chlorine........do....	2.917	3.622	8.898	4.028
(u) Sodium chloride........do....	4.817	5.976	14.685	6.646
(v) Heat of combustion........calories..	72	116	75	97

	Experiment No. 81. A. H. M.		Experiment No. 82. H. C. K.	
	Nov 21-22, 1905.	Nov. 22-23, 1905.	Nov. 24-25, 1905.	Nov. 25-26, 1905.
(a) Weight........grams..	660.0	831.2	575.7	1795.0
(b) Water........do....	621.26	783.16	538.57	1740.07
(c) Solids, a—b........do....	38.74	48.04	37.13	54.93
(d) Ash........do....	12.61	11.22	9.67	16.33
(e) Organic matter, c—d........do....	26.13	36.82	27.46	38.60
(f) Nitrogen........do....	9.11	13.05	9.38	14.36
(g) Carbon........do....	7.52	9.48	7.71	10.77
(h) Hydrogen in organic matter.....do....	2.18	2.91	2.07	3.59
(i) Oxygen (by difference) in organic matter, e—(f+g+h)........grams..	7.32	11.38	8.30	9.88
(j) Phosphorus........do....	.643	1.060	.486	.873
Phosphoric acid (P_2O_5):				
(k) by fusion........grams..	1.472	2.429	1.113	2.000
(l) by titration........do....	1.470	2.505	1.132	2.017
(m) Sulphur........do...	.572	.817	.570	.768
Sulphur trioxide (SO_3):				
(n) Total........grams..	1.427	2.036	1.423	1.915
(o) Inorganic and ethereal........do....	1.295	1.891	1.230	1.746
(p) Neutral, n—o........do....	.132	.145	.193	.169
(q) Creatinine (preformed)........do....	1.184	1.229	1.643	1.730
(r) Total creatinine........do....	1.226	1.357	1.726	1.795
(s) Creatine[1] (preformed), r—q.....do....	.042	.128	.083	.065
(t) Chlorine........do....	3.880	2.794	3.451	6.714
(u) Sodium chloride........do ...	6.402	4.612	5.694	11.079
(v) Heat of combustion........calories..	80	109	88	122

[1] In terms of creatinine.

TABLE 165.—*Weight, composition, and heat of combustion of urine*—Continued.

	Experiment No. 83. H. R. D.		Experiment No. 85. N. M. P.		Experiment No. 89. D.W.	
	Dec. 5-6, 1905.	Dec. 6-7, 1905.	Dec. 9-10, 1905.	Dec. 10-11, 1906.	Jan. 10-11, 1906.	Jan. 11-12, 1906.
(*a*) Weight...........grams.	1204.5	1065.0	[1] 34.6 1188.0	679.4	644.4	539.6
(*b*) Water..............do...	1159.21	1012.39	[1] 33.37 1145.11	642.44	599.55	492.22
(*c*) Solids, *a*—*b*........do...	45.29	52.61	[1] 1.25 42.89	36.96	44.85	47.38
(*d*) Ash................do...	8.19	8.73	[1] .36 12.47	5.57	13.34	7.45
(*e*) Organic matter, *c*—*d*..do...	37.10	43.88	[1] .89 30.42	31.39	31.51	39.93
(*f*) Nitrogen ....do...	13.25	13.53	[2] .32 11.05	11.35	9.99	14.46
(*g*) Carbon ....do...	9.76	12.78	[1] .22 7.48	8.22	8.38	9.87
(*h*) Hydrogen in organic matter ....grams.	2.65	3.20	[1] .06 1.90	2.11	2.26	2.81
(*i*) Oxygen (by difference) in organic matter, *e*—(*f*+*g*+*h*) ....grams.	11.44	14.37	[1] .29 9.99	9.71	10.88	12.79
(*j*) Phosphorus.........do...	1.051	1.219	[3] .549	.519	1.027	1.368
Phosphoric acid (P_2O_5):						
(*k*) by fusion......grams.	2.407	2.793	[3] 1.257	1.189	2.354	3.134
(*l*) by titration......do...	2.414	2.829	[3] 1.283	1.516	....	....
(*m*) Sulphur.. ....do...	.871	.703	[3] .604	.603	.693	.861
Sulphur trioxide (SO_3):						
(*n*) Total..........grams.	2.173	1.755	[3] 1.507	1.506	1.731	2.148
(*o*) Inorganic and ethereal, grams...	1.961	1.580	[3] 1.219	1.331	1.472	1.831
(*p*) Neutral, *n*—*o*..grams.	.212	.175	[3] .288	.175	.258	.317
(*q*) Creatinine (preformed), grams..............	1.217	1.129	[3] 1.525	1.541	2.028	1.922
(*r*) Total creatinine...grams.	1.317	1.363	[3] 1.543	1.703	2.091	1.966
(*s*) Creatine[4] (preformed), *r*—*q*...........grams..	.100	.234	[3] .018	.162	.063	.044
(*t*) Chlorine............do...	.517	.628	[3] 4.582	1.461	5.857	1.805
(*u*) Sodium chloride....do...	.853	1.036	[3] 7.562	2.411	9.666	2.978
(*v*) Heat of combustion.cals..	116	151	[1] 3 93	99	93	114

[1] Calculated. See p. 243.
[2] Amount of nitrogen determined for urine lost. See p. 243.
[3] Does not include possible amount in urine lost.
[4] In terms of creatinine.

TABLE 166.—*Record of water of respiration and perspiration—Metabolism experiments Nos. 79-83, 85, and 89.*[1]

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 79. H. E. S.		
1905.		
Oct. 13:		
Preliminary:	*Grams.*	*Grams.*
5 a.m. to 7 a.m.	51.6	...
Oct. 13-14:		
7 a.m. to 9 a.m.	53.8	53.0
9 a.m. 11 a.m.	50.4	55.5
11 a.m. 1 p.m.	51.2	55.6
1 p.m. 3 p.m.	48.6	55.6
3 p.m. 5 p.m.	50.0	54.8
5 p.m. 7 p.m.	49.4	55.7
7 p.m. 9 p.m.	48.3	52.9
9 p.m. 11 p.m.	47.4	54.4
11 p.m. 1 a.m.	49.0	54.1
1 a.m. 3 a.m.	53.6	63.0
3 a.m. 5 a.m.	53.0	54.2
5 a.m. 7 a.m.	52.3	58.2
Total	....	667.0
Oct. 14-15:		
7 a.m. to 9 a.m.	57.2	55.2
9 a.m. 11 a.m.	54.2	57.7
11 a.m. 1 p.m.	57.2	63.9
1 p.m. 3 p.m.	53.9	57.9
3 p.m. 5 p.m.	54.7	58.8
5 p.m. 7 p.m.	50.8	59.8
7 p.m. 9 p.m.	50.8	61.2
9 p.m. 11 p.m.	49.7	61.4
11 p.m. 1 a.m.	53.3	59.8
1 a.m. 3 a.m.	54.4	61.0
3 a.m. 5 a.m.	54.0	54.2
5 a.m. 7 a.m.	50.4	53.2
Total	....	704.1

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 80. C. R. Y.		
1905.		
Oct. 26-27:		
Preliminary:	*Grams.*	*Grams.*
11 p.m.	51.7	....
11 p.m. to 1 a.m.	51.1	66.1
1 a.m. 3 a.m.	56.4	83.2
3 a.m. 5 a.m.	58.2	76.9
5 a.m. 7 a.m.	54.2	75.6
Total, 8 hours	....	[2] 301.8
Oct. 27-28:		
7 a.m. to 9 a.m.	55.7	67.2
9 a.m. 11 a.m.	49.6	47.5
11 a.m. 1 p.m.	46.0	84.2
1 p.m. 3 p.m.	41.2	74.3
3 p.m. 5 p.m.	43.5	75.7
5 p.m. 7 p.m.	38.4	76.1
7 p.m. 9 p.m.	37.8	70.1
9 p.m. 11 p.m.	34.8	71.0
11 p.m. 1 a.m.	40.2	73.2
1 a.m. 3 a.m.	47.2	95.2
3 a.m. 5 a.m.	52.2	88.6
5 a.m. 7 a.m.	53.9	103.7
Total	....	926.8
Oct. 28-29:		
7 a.m. to 9 a.m.	57.3	92.2
9 a.m. 11 a.m.	47.1	77.4
11 a.m. 1 p.m.	50.1	88.0
1 p.m. 3 p.m.	46.4	95.4
3 p.m. 5 p.m.	45.2	89.5
5 p.m. 7 p.m.	42.9	91.9
7 p.m. 9 p.m.	42.9	83.0
9 p.m. 11 p.m.	40.2	83.2
11 p.m. 1 a.m.	51.5	95.2
1 a.m. 3 a.m.	46.9	92.8
3 a.m. 5 a.m.	46.4	85.0
5 a.m. 7 a.m.	50.4	86.9
Total	....	1060.5

[1] Allowance has been made for water gained or lost by chair, bedding and miscellaneous articles as follows: Experiment No. 79, October 13-14, 17.0 grams lost; October 14-15, 6.8 grams lost; experiment No. 80, October 27-28, 17.8 grams lost.

[2] Does not include corrections for changes in weight of chair and bedding.

TABLE 166.—*Record of water of respiration and perspiration*[1]—Continued.

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 81. A. H. M.		
1905.		
Nov. 21:		
Preliminary:	*Grams.*	*Grams.*
1 a.m.	33.3	....
1 a.m. to 3 a.m.	30.3	60.0
3 a.m. 5 a.m.	27.9	55.6
5 a.m. 7 a.m.	25.4	53.9
Total, 6 hours	....	[2]169.5
Nov. 21-22:		
7 a.m. to 9 a.m.	31.5	56.1
9 a.m. 11 a.m.	32.1	63.4
11 a.m. 1 p.m.	29.0	54.6
1 p.m. 3 p.m.	28.1	51.8
3 p.m. 5 p.m.	26.3	51.6
5 p.m. 7 p.m.	25.6	52.6
7 p.m. 9 p.m.	25.3	48.3
9 p.m. 11 p.m.	23.9	43.6
11 p.m. 1 a.m.	24.1	46.6
1 a.m. 3 a.m.	24.7	45.6
3 a.m. 5 a.m.	25.5	45.3
5 a.m. 7 a.m.	26.5	49.1
Total	....	608.6
Nov. 22-23:		
7 a.m. to 9 a.m.	31.3	56.5
9 a.m. 11 a.m.	30.1	64.3
11 a.m. 1 p.m.	27.8	55.1
1 p.m. 3 p.m.	25.1	50.9
3 p.m. 5 p.m.	25.6	49.7
5 p.m. 7 p.m.	26.9	58.2
7 p.m. 9 p.m.	27.3	56.4
9 p.m. 11 p.m.	27.5	57.5
11 p.m. 1 a.m.	27.7	55.2
1 a.m. 3 a.m.	27.1	55.7
3 a.m. 5 a.m.	26.3	54.7
5 a.m. 7 a.m.	28.6	56.5
Total	....	670.7

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 82. H. C. K.		
1905.		
Nov. 23-24:		
Preliminary:	*Grams.*	*Grams.*
7 p.m.	47.1	....
7 p.m. to 9 p.m.	36.1	73.7
9 p.m. 11 p.m.	31.0	67.5
11 p.m. 1 a.m.	32.1	69.6
1 a.m. 3 a.m.	29.4	64.5
3 a.m. 5 a.m.	31.0	65.2
5 a.m. 7 a.m.	34.0	77.0
Total, 12 hours	....	[2]417.6
Nov. 24-25:		
7 a.m. to 9 a.m.	45.0	99.4
9 a.m. 11 a.m.	39.7	87.0
11 a.m. 1 p.m.	38.9	59.8
1 p.m. 3 p.m.	35.9	72.8
3 p.m. 5 p.m.	33.8	73.8
5 p.m. 7 p.m.	30.4	67.7
7 p.m. 9 p.m.	32.1	70.5
9 p.m. 11 p.m.	29.6	65.3
11 p.m. 1 a.m.	31.3	64.8
1 a.m. 3 a.m.	33.1	50.4
3 a.m. 5 a.m.	31.9	63.6
5 a.m. 7 a.m.	31.8	67.0
Total	....	842.1
Nov. 25-26:		
7 a.m. to 9 a.m.	48.5	110.2
9 a.m. 11 a.m.	40.1	85.8
11 a.m. 1 p.m.	38.8	78.3
1 p.m. 3 p.m.	34.7	75.8
3 p.m. 5 p.m.	33.8	74.4
5 p.m. 7 p.m.	31.7	74.0
7 p.m. 9 p.m.	38.0	84.2
9 p.m. 11 p.m.	35.3	80.2
11 p.m. 1 a.m.	35.2	72.9
1 a.m. 3 a.m.	34.2	57.8
3 a.m. 5 a.m.	35.0	69.5
5 a.m. 7 a.m.	35.2	77.4
Total	....	940.5

[1] Allowance has been made for water gained or lost by chair, bedding, and miscellaneous articles as follows: Experiment No. 81, November 21-22, 47.9 grams lost; November 22-23, 4.9 grams lost; experiment No. 82, November 24-25, 10.0 grams lost; November 25-26, 24.0 grams gained.

[2] Does not include corrections for changes in weight of chair and bedding.

TABLE 166.—*Record of water of respiration and perspiration*[1]—Continued.

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 83. H. R. D.		
1905.		
Dec. 4–5:		
Preliminary:	*Grams.*	*Grams.*
11 p.m.	36.7	....
11 p.m. to 1 a.m.	40.2	47.1
1 a.m. 3 a.m.	35.4	73.0
3 a.m. 5 a.m.	34.2	62.4
5 a.m. 7 a.m.	30.9	60.3
Total, 8 hours	....	[2]272.8
Dec. 5–6:		
7 a.m. to 9 a.m.	38.6	68.3
9 a.m. 11 a.m.	31.8	57.4
11 a.m. 1 p.m.	32.2	57.9
1 p.m. 3 p.m.	28.2	53.2
3 p.m. 5 p.m.	27.3	51.7
5 p.m. 7 p.m.	31.3	60.5
7 p.m. 9 p.m.	29.5	58.6
9 p.m. 11 p.m.	26.8	52.8
11 p.m. 1 a.m.	28.3	53.3
1 a.m. 3 a.m.	30.7	61.2
3 a.m. 5 a.m.	30.1	53.3
5 a.m. 7 a.m.	29.7	56.3
Total	....	684.5
Dec. 6–7:		
7 a.m. to 9 a.m.	38.6	78.8
9 a.m. 11 a.m.	29.3	52.5
11 a.m. 1 p.m.	29.8	59.9
1 p.m. 3 p.m.	27.6	52.3
3 p.m. 5 p.m.	28.1	54.6
5 p.m. 7 p.m.	26.7	54.0
7 p.m. 9 p.m.	28.8	58.1
9 p.m. 11 p.m.	26.8	53.6
11 p.m. 1 a.m.	29.4	55.4
1 a.m. 3 a.m.	28.0	51.8
3 a.m. 5 a.m.	27.8	48.1
5 a.m. 7 a.m.	29.9	52.9
Total	....	672.0

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 85. N. M. P.		
1905.		
Dec. 8–9:		
Preliminary:	*Grams.*	*Grams.*
11 p.m.	34.5	....
11 p.m. to 1 a.m.	36.1	70.2
1 a.m. 3 a.m.	34.9	60.7
3 a.m. 5 a.m.	30.5	59.0
5 a.m. 7 a.m.	31.4	57.7
Total, 8 hours	....	[2]247.6
Dec. 9–10:		
7 a.m. to 9 a.m.	38.1	76.8
9 a.m. 11 a.m.	36.6	68.4
11 a.m. 1 p.m.	30.6	66.5
1 p.m. 3 p.m.	31.5	59.6
3 p.m. 5 p.m.	28.3	59.6
5 p.m. 7 p.m.	31.3	65.4
7 p.m. 9 p.m.	32.7	73.6
9 p.m. 11 p.m.	30.4	61.3
11 p.m. 1 a.m.	29.9	62.8
1 a.m. 3 a.m.	30.5	60.0
3 a.m. 5 a.m.	30.9	59.9
5 a.m. 7 a.m.	32.0	61.9
Total	....	775.8
Dec. 10–11:		
7 a.m. to 9 a.m.	40.2	73.7
9 a.m. 11 a.m.	35.9	63.4
11 a.m. 1 p.m.	35.5	65.5
1 p.m. 3 p.m.	34.4	61.2
3 p.m. 5 p.m.	33.4	59.9
5 p.m. 7 p.m.	34.3	68.7
7 p.m. 9 p.m.	36.1	70.1
9 p.m. 11 p.m.	33.9	68.9
11 p.m. 1 a.m.	35.8	68.0
1 a.m. 3 a.m.	37.5	72.9
3 a.m. 5 a.m.	38.2	67.9
5 a.m. 7 a.m.	37.0	73.2
Total	....	813.4

[1] Allowance has been made for water gained or lost by chair, bedding, and miscellaneous articles as follows: Experiment No. 83, December 5-6, 44.0 grams lost; December 6-7, 13.0 grams lost; experiment No. 85, December 9-10, 38.0 grams gained; December 10-11, 7.0 grams lost.

[2] Does not include corrections for changes in weight of chair and bedding.

TABLE 166.—*Record of water of respiration and perspiration*[1]—Continued.

Date and period.	(a) Total amount of vapor in chamber at end of period.	(b) Total water of respiration and perspiration.
EXPERIMENT No. 89. D. W.		
1906.		
Jan. 9–10:		
Preliminary:	*Grams.*	*Grams.*
11 p.m.	37.7	....
11 p.m. to 1 a.m.	39.2	44.6
1 a.m. 3 a.m.	41.3	44.4
3 a.m. 5 a.m.	40.1	46.1
5 a.m. 7 a.m.	39.6	42.4
Total, 8 hours	...	[2]177.5
Jan. 10–11:		
7 a.m. to 9 a.m.	36.5	68.1
9 a.m. 11 a.m.	33.7	64.1
11 a.m. 1 p.m.	33.0	66.1
1 p.m. 3 p.m.	36.5	71.0
3 p.m. 5 p.m.	31.5	64.6
5 p.m. 7 p.m.	33.5	71.1
7 p.m. 9 p.m.	35.7	72.5
9 p.m. 11 p.m.	38.8	73.2
11 p.m. 1 a.m.	36.2	69.2
1 a.m. 3 a.m.	33.2	63.5
3 a.m. to 5 a.m.	32.0	68.0
5 a.m. 7 a.m.	35.1	68.2
Total	....	819.6
Jan. 11–12:		
7 a.m. to 9 a.m.	34.9	65.7
9 a.m. 11 a.m.	32.1	61.2
11 a.m. 1 p.m.	34.4	68.5
1 p.m. 3 p.m.	36.8	64.5
3 p.m. 5 p.m.	32.7	61.9
5 p.m. 7 p.m.	37.2	73.7
7 p.m. 9 p.m.	37.2	79.9
9 a.m. 11 p.m.	37.7	69.2
11 p.m. 1 a.m.	36.2	69.9
1 a.m. 3 a.m.	33.5	61.6
3 a.m. 5 a.m.	32.3	64.2
5 a.m. 7 a.m.	31.6	62.4
Total	....	802.7

[1] Allowance has been made for water gained or lost by chair, bedding, and miscellaneous articles as follows: Experiment No. 89, January 10-11, 9.5 grams lost; January 11-12, 0.3 gram lost.

[2] Does not include corrections for changes in weight of chair and bedding.

TABLE 167.—*Record of carbon dioxide and oxygen—Metabolism experiments Nos. 79-83, 85, and 89.*

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
EXPERIMENT No. 79. H. E. S.					
1905. Oct. 12–13...	Preliminary:	*Grams.*	*Grams.*	*Liters.*	*Grams.*
	11 p. m.	48.9	....	.....	....
	11 p. m. to 1 a. m.	46.6	52.7	.....	....
	1 a. m. 3 a. m.	39.5	41.0	.....	....
	3 a. m. 5 a. m.	44.4	48.1	.....	....
	5 a. m. 7 a. m.	39.9	41.2	893.7	....
	Total, 8 hours	....	183.0	.....	....
Oct. 13–14...	7 a. m. to 9 a. m.	55.4	67.8	881.9	67.3
	9 a. m. 11 a. m.	50.5	54.2	884.6	42.7
	11 a. m. 1 p. m.	51.1	55.1	877.2	49.7
	1 p. m. 3 p. m.	51.2	57.4	878.3	48.5
	3 p. m. 5 p. m.	49.4	50.7	877.2	47.9
	5 p. m. 7 p. m.	47.8	51.7	882.2	49.6
	7 p. m. 9 p. m.	46.3	50.4	889.1	42.0
	9 p. m. 11 p. m.	46.5	51.2	887.7	52.0
	11 p. m. 1 a. m.	46.8	51.0	886.9	41.8
	1 a. m. 3 a. m.	49.8	52.0	886.1	51.3
	3 a. m. 5 a. m.	47.0	43.4	894.7	36.7
	5 a. m. 7 a. m.	46.0	47.1	903.0	46.4
	Total	....	632.0	.....	575.9
Oct. 14–15...	7 a. m. to 9 a. m.	62.9	65.7	899.5	66.4
	9 a. m. 11 a. m.	58.6	54.9	903.2	45.2
	11 a. m. 1 p. m.	57.6	54.1	894.7	53.2
	1 p. m. 3 p. m.	59.2	56.3	896.0	55.0
	3 p. m. 5 p. m.	57.5	51.3	898.7	51.5
	5 p. m. 7 p. m.	55.6	54.6	909.3	46.9
	7 p. m. 9 p. m.	48.5	56.8	913.6	52.4
	9 p. m. 11 p. m.	40.1	45.3	919.2	47.8
	11 p. m. 1 a. m.	43.7	51.3	908.8	51.8
	1 a. m. 3 a. m.	45.4	52.1	903.2	48.8
	3 a. m. 5 a. m.	44.3	45.5	907.5	43.4
	5 a. m. 7 a. m.	43.2	47.3	912.7	42.9
	Total	....	635.2	.....	605.3
EXPERIMENT No. 80. C. R. Y.					
1905. Oct. 26–27...	Preliminary:				
	11 p. m.	52.2	....	935.8	....
	11 p. m. to 1 a. m.	40.2	61.6	941.3	32.2
	1 a. m. 3 a. m.	32.3	47.5	932.4	40.4
	3 a. m. 5 a. m.	32.3	50.2	933.8	39.1
	5 a. m. 7 a. m.	32.7	52.4	948.9	33.0
	Total, 8 hours	....	211.7	.....	144.7

TABLE 167.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
EXPERIMENT No. 80. C. R. Y. (Cont'd).					
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Oct. 27–28...	7 a. m. to 9 a. m..	45.4	73.6	938.7	70.8
	9 a. m. 11 a. m..	42.1	58.7	950.6	43.9
	11 a. m. 1 p. m..	32.7	55.2	950.8	46.3
	1 p. m. 3 p. m..	24.7	49.0	955.8	39.3
	3 p. m. 5 p. m..	30.9	51.3	945.6	50.8
	5 p. m. 7 p. m..	22.5	46.2	960.4	43.9
	7 p. m. 9 p. m..	25.0	43.3	960.9	42.2
	9 p. m. 11 p. m..	19.5	43.6	966.8	40.3
	11 p. m. 1 a. m..	24.2	58.7	956.3	55.8
	1 a. m. 3 a. m..	23.8	47.0	944.2	43.7
	3 a. m. 5 a. m..	27.3	50.8	936.3	51.8
	5 a. m. 7 a. m..	24.1	50.0	937.4	47.4
	Total.............	....	627.4	.....	576.2
Oct. 28–29...	7 a. m. to 9 a. m..	35.6	64.3	928.5	68.7
	9 a. m. 11 a. m..	27.2	55.0	946.7	48.1
	11 a. m. 1 p. m..	30.9	49.5	938.1	46.6
	1 p. m. 3 p. m..	24.4	52.0	941.2	53.2
	3 p. m. 5 p. m..	28.2	48.2	948.7	49.6
	5 p. m. 7 p. m..	25.0	56.5	957.4	59.5
	7 p. m. 9 p. m..	22.2	51.6	960.3	48.8
	9 p. m. 11 p. m..	23.5	49.3	966.5	44.1
	11 p. m. 1 a. m..	23.4	57.0	952.1	59.0
	1 a. m. 3 a. m..	21.9	47.7	957.1	43.7
	3 a. m. 5 a. m..	24.0	52.5	963.0	53.7
	5 a. m. 7 a. m..	32.3	56.6	958.5	53.5
	Total.............	....	640.3	.....	628.5
EXPERIMENT No. 81. A. H. M.					
1905.	Preliminary:				
Nov. 21......	1 a. m............	26.1	....	946.4	....
	1 a. m. to 3 a. m..	15.6	34.7	956.0	28.1
	3 a. m. 5 a. m..	21.0	37.9	956.7	30.9
	5 a. m. 7 a. m..	18.7	39.9	957.6	32.2
	Total, 6 hours......	....	112.5	.....	91.2
Nov. 21–22...	7 a. m. to 9 a. m..	28.2	61.6	952.1	52.6
	9 a. m. 11 a. m..	29.5	53.1	945.5	52.7
	11 a. m. 1 p. m..	27.4	45.7	941.5	41.6
	1 p. m. 3 p. m..	28.1	42.4	934.4	42.4
	3 p. m. 5 p. m..	29.4	45.8	938.3	46.3
	5 p. m. 7 p. m..	29.1	44.0	942.6	45.5
	7 p. m. 9 p. m..	31.7	44.3	941.2	44.9
	9 p. m. 11 p. m..	21.0	44.4	942.9	41.0
	11 p. m. 1 a. m..	25.3	37.9	935.5	36.6
	1 a. m. 3 a. m..	18.4	35.5	936.4	38.9
	3 a. m. 5 a. m..	19.3	40.1	937.3	35.4
	5 a. m. 7 a. m..	21.3	39.9	925.2	38.9
	Total.............	....	534.7	.....	516.8

TABLE 167.—*Record of carbon dioxide and oxygen*—Continued.

EXPERIMENT No. 81. A. H. M. (Cont'd).

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Nov. 22–23...	7 a. m. to 9 a. m..	29.0	59.7	914.4	62.3
	9 a. m. 11 a. m..	30.8	51.7	909.5	50.5
	11 a. m. 1 p. m..	27.4	49.2	898.8	46.7
	1 p. m. 3 p. m..	25.0	38.3	900.4	35.1
	3 p. m. 5 p. m..	22.1	37.3	894.3	33.3
	5 p. m. 7 p. m..	29.3	44.8	882.4	52.8
	7 p. m. 9 p. m..	28.1	46.9	878.9	43.1
	9 p. m. 11 p. m..	30.1	39.6	877.2	45.9
	11 p. m. 1 a. m..	27.5	41.6	877.0	40.8
	1 a. m. 3 a. m..	29.7	33.9	870.4	32.2
	3 a. m. 5 a. m..	26.5	36.3	874.6	38.8
	5 a. m. 7 a. m..	22.0	45.0	872.0	45.6
	Total.............	....	524.3	.....	527.1

EXPERIMENT No. 82. H. C. K.

Date.	Period.	(a)	(b)	(c)	(d)
1905.	Preliminary:				
Nov. 23–24...	7 p. m............	44.4	....	885.4	....
	7 p. m. to 9 p. m..	34.9	69.9	900.1	55.3
	9 p. m. 11 p. m..	29.6	62.1	904.3	50.8
	11 p. m. 1 a. m..	25.5	60.2	897.6	46.0
	1 a. m. 3 a. m..	23.5	46.5	902.5	33.9
	3 a. m. 5 a. m..	24.1	51.5	896.8	46.7
	5 a. m. 7 a. m..	27.2	52.0	889.0	....
	Total, 12 hours	....	342.2	.....	....
Nov. 24–25...	7 a. m. to 9 a. m..	35.5	82.7	868.2	80.2
	9 a. m. 11 a. m..	39.3	72.1	863.9	65.9
	11 a. m. 1 p. m..	43.3	65.8	844.9	54.3
	1 p. m. 3 p. m..	43.6	71.3	840.8	63.7
	3 p. m. 5 p. m..	33.1	56.0	848.0	47.2
	5 p. m. 7 p. m..	34.2	56.7	848.0	47.1
	7 p. m. 9 p. m..	42.7	70.4	834.2	69.2
	9 p. m. 11 p. m..	32.1	62.9	840.8	58.4
	11 p. m. 1 a. m..	36.9	55.8	827.1	47.3
	1 a. m. 3 a. m..	37.9	47.7	821.4	44.6
	3 a. m. 5 a. m..	25.7	48.3	826.4	41.5
	5 a. m. 7 a. m..	29.4	51.2	824.2	43.9
	Total.............	....	740.9	.....	663.3

TABLE 167.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
EXPERIMENT No. 82. H. C. K. (Cont'd).					
1905.		*Grams.*	*Grams.*	*Liters.*	*Grams.*
Nov. 25–26...	7 a. m. to 9 a. m..	40.7	88.8	803.5	85.6
	9 a. m. 11 a. m..	36.3	63.0	814.1	59.4
	11 a. m. 1 p. m..	42.5	72.0	801.6	70.9
	1 p. m. 3 p. m..	42.0	62.8	812.1	59.3
	3 p. m. 5 p. m..	42.2	64.2	819.2	51.8
	5 p. m. 7 p. m..	39.8	56.7	822.9	57.1
	7 p. m. 9 p. m..	53.0	71.1	809.1	75.4
	9 p. m. 11 p. m..	53.0	71.3	813.3	68.9
	11 p. m. 1 a. m..	34.2	55.1	812.3	50.4
	1 a. m. 3 a. m..	43.5	50.5	803.4	44.8
	3 a. m. 5 a. m..	38.1	52.7	805.2	52.8
	5 a. m. 7 a. m..	34.0	59.1	800.2	57.4
	Total.............	....	767.3	.....	733.8
EXPERIMENT No. 83. H. R. D.					
1905.	Preliminary.				
Dec. 4–5.....	11 p. m.............	25.8	....	924.6	....
	11 p. m. to 1 a. m..	26.8	49.4	925.4	45.8
	1 a. m. 3 a. m..	21.7	36.6	942.4	32.4
	3 a. m. 5 a. m..	25.7	40.2	946.1	41.9
	5 a. m. 7 a. m..	23.4	42.6	960.6	32.6
	Total, 8 hours	....	168.8	.....	152.7
Dec. 5–6.....	7 a. m. to 9 a. m..	33.1	67.8	952.6	76.9
	9 a. m. 11 a. m..	29.7	56.1	961.6	48.1
	11 a. m. 1 p. m..	32.1	58.4	956.5	58.8
	1 p. m. 3 p. m..	24.9	44.8	967.0	35.5
	3 p. m. 5 p. m..	28.4	51.1	970.3	51.8
	5 p. m. 7 p. m..	26.6	45.0	957.6	41.4
	7 p. m. 9 p. m..	30.6	54.4	960.4	61.6
	9 p. m. 11 p. m..	29.0	50.5	963.1	38.4
	11 p. m. 1 a. m..	28.6	48.4	956.1	49.0
	1 a. m. 3 a. m..	26.9	41.3	957.2	36.0
	3 a. m. 5 a. m..	28.2	42.9	946.2	45.5
	5 a. m. 7 a. m..	29.7	46.0	945.5	42.2
	Total.............	....	606.7	.....	585.2

TABLE 167.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
EXPERIMENT No. 86. H. R. D. (Cont'd).					
		Grams.	*Grams.*	*Liters.*	*Grams.*
1905. Dec. 6-7.....	7 a. m. to 9 a. m..	41.6	67.6	926.4	74.2
	9 a. m. 11 a. m..	34.8	46.4	941.3	32.8
	11 a. m. 1 p. m..	38.3	55.3	927.1	59.3
	1 p. m. 3 p. m..	34.6	44.6	925.2	32.0
	3 p. m. 5 p. m..	39.6	51.6	923.7	55.6
	5 p. m. 7 p. m..	35.4	42.2	925.0	38.9
	7 p. m. 9 p. m..	29.0	56.3	922.3	65.4
	9 p. m. 11 p. m..	34.3	45.2	918.7	29.9
	11 p. m. 1 a. m..	23.6	42.6	920.5	36.1
	1 a. m. 3 a. m..	21.6	38.9	919.6	43.9
	3 a. m. 5 a. m..	23.4	41.5	913.8	39.0
	5 a. m. 7 a. m..	26.1	47.0	912.4	47.3
	Total.............	....	579.2	.....	554.4
EXPERIMENT No. 85. N. M. P.					
1905. Dec. 8-9.....	Preliminary: 11 p. m............	31.2	....	911.6	....
	11 p. m. to 1 a. m..	29.3	58.3	908.6	53.0
	1 a. m. 3 a. m..	28.1	50.2	912.3	41.7
	3 a. m. 5 a. m..	24.9	47.2	916.8	33.1
	5 a. m. 7 a. m..	27.5	51.9	916.5	47.7
	Total, 8 hours......	....	207.6	.....	175.5
Dec. 9-10....	7 a. m. to 9 a.m ..	37.4	78.1	904.0	69.7
	9 a. m. 11 a. m..	35.7	62.4	896.1	55.8
	11 a. m. 1 p. m..	39.8	70.1	890.3	57.0
	1 p. m. 3 p. m..	33.3	55.5	888.1	47.8
	3 p. m. 5 p. m..	31.0	55.4	883.1	52.1
	5 p. m. 7 p. m..	31.1	57.2	870.7	49.4
	7 p. m. 9 p. m..	34.0	65.4	854.7	67.1
	9 p. m. 11 p. m..	29.4	54.7	841.8	51.1
	11 p. m. 1 a. m..	27.9	52.0	828.3	39.9
	1 a. m. 3 a. m..	26.6	46.9	808.9	46.2
	3 a. m. 5 a. m..	31.5	49.9	789.4	46.0
	5 a. m. 7 a. m..	28.4	49.0	778.7	45.4
	Total.............	....	696.6	.....	627.5

TABLE 167.—*Record of carbon dioxide and oxygen*—Continued.

Date.	Period.	Carbon dioxide. (a) Amount in chamber at end of period.	Carbon dioxide. (b) Total weight exhaled by subject.	Oxygen. (c) Amount in chamber at end of period.	Oxygen. (d) Total amount consumed by subject.
EXPERIMENT No. 85. N. M. P. (Cont'd).					
1905. Dec. 10–11...	7 a. m. to 9 a. m..	39.9	77.0	756.6	67.3
	9 a. m. 11 a. m..	34.2	62.2	759.3	50.9
	11 a. m. 1 p. m..	34.3	61.8	753.0	61.9
	1 p. m. 3 p. m..	34.4	61.9	760.2	61.9
	3 p. m. 5 p. m..	34.5	56.6	775.4	50.2
	5 p. m. 7 p. m..	30.4	55.7	789.0	56.9
	7 p. m. 9 p. m..	35.0	67.5	788.8	67.1
	9 p. m. 11 p. m..	30.3	61.5	802.3	59.3
	11 p. m. 1 a. m..	28.9	56.2	801.5	51.2
	1 a. m. 3 a. m..	26.3	50.7	798.5	48.7
	3 a. m. 5 a. m..	28.7	52.9	795.6	50.5
	5 a. m. 7 a. m..	28.7	55.3	793.0	49.8
	Total..............	....	719.3	.....	675.6
EXPERIMENT No. 89. D. W.					
1906. Jan. 9–10....	Preliminary:				
	11 p. m.............	42.6	....	938.3	....
	11 p. m. to 1 a. m..	33.4	66.2	943.3	54.8
	1 a. m. 3 a. m..	29.7	51.5	946.6	45.9
	3 a. m. 5 a. m..	30.4	55.2	957.1	45.0
	5 a. m. 7 a. m..	31.2	52.7	957.3	50.9
	Total, 8 hours	....	225.6	.....	196.6
Jan. 10–11...	7 a. m. to 9 a. m..	35.9	75.1	965.7	62.4
	9 a. m. 11 a. m..	28.9	57.3	975.4	37.4
	11 a. m. 1 p. m..	28.9	53.2	959.9	46.8
	1 p. m. 3 p. m..	33.8	65.6	950.4	67.1
	3 p. m. 5 p. m..	29.1	54.4	964.6	40.0
	5 p. m. 7 p. m..	30.6	63.5	958.8	68.4
	7 p. m. 9 p. m..	38.4	69.4	953.9	56.3
	9 p. m. 11 p. m..	39.7	74.6	949.8	79.5
	11 p. m. 1 a. m..	33.5	50.3	956.0	38.9
	1 a. m. 3 a. m..	25.6	48.2	966.2	46.0
	3 a. m. 5 a. m..	34.9	56.8	966.6	47.7
	5 a. m. 7 a. m..	29.6	54.0	965.1	54.9
	Total..............	....	722.4	.....	645.4
Jan. 11–12...	7 a. m. to 9 a. m..	45.8	65.7	964.1	67.3
	9 a. m. 11 a. m..	29.6	54.5	976.7	44.4
	11 a. m. 1 p. m..	43.7	58.6	957.4	52.6
	1 p. m. 3 p. m..	38.8	66.0	951.4	74.7
	3 p. m. 5 p. m..	44.7	50.8	942.0	49.7
	5 p. m. 7 p. m..	36.0	66.9	942.8	74.6
	7 p. m. 9 p. m..	61.4	75.1	922.2	65.7
	9 p. m. 11 p. m..	40.3	67.7	921.2	76.1
	11 p. m. 1 a. m..	54.7	53.0	907.9	40.4
	1 a. m. 3 a. m..	30.5	49.5	917.9	49.8
	3 a. m. 5 a. m..	28.7	50.3	912.3	48.2
	5 a. m. 7 a. m..	25.2	47.4	908.2	37.8
	Total..............	....	705.5	.....	681.3

TABLE 168.—*Elements katabolized in body—Metabolism experiments Nos. 79-83, 85, and 89.*

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
EXPERIMENT No. 79. H.E.S.						
First day, Oct. 13, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air....	575.90	....	....	....	575.90	....
Outgo:						
Water in urine...........	996.08	....	....	111.46	884.62	....
Solids in urine...........	31.12	8.11	6.27	1.75	6.26	8.73
Water of respiration[1].....	666.98	....	....	74.64	592.34	....
Carbon dioxide...........	632.02	....	172.38	....	459.64	....
Total..................	2326.20	8.11	178.65	187.85	1942.86	8.73
Loss..................	1750.30	8.11	178.65	187.85	1366.96	8.73
Second day, Oct. 14, 1905.						
Income: Oxygen from air....	605.27	....	....	....	605.27	....
Outgo:						
Water in urine...........	809.96	....	....	90.63	719.33	....
Solids in urine...........	49.14	14.35	10.22	3.09	10.31	11.17
Water of respiration[1].....	704.07	....	....	78.79	625.28	....
Carbon dioxide...........	635.18	....	173.24	....	461.94	....
Total..................	2198.35	14.35	183.46	172.51	1816.86	11.17
Loss..................	1593.08	14.35	183.46	172.51	1211.59	11.17
EXPERIMENT No. 80. C.R.Y.						
First day, Oct. 27, 1905.						
Income: Oxygen from air....	576.21	....	....	....	576.21	....
Outgo:						
Water in urine...........	1105.75	....	....	123.73	982.02	....
Solids in urine...........	41.65	7.78	7.11	2.07	5.76	18.93
Water of respiration[1].....	926.76	....	....	103.70	823.06	....
Carbon dioxide...........	627.38	....	171.11	....	456.27	....
Total..................	2701.54	7.78	178.22	229.50	2267.11	18.93
Loss..................	2125.33	7.78	178.22	229.50	1690.90	18.93
Second day, Oct. 28, 1905.						
Income: Oxygen from air....	628.55	....	....	....	628.55	....
Outgo:						
Water in urine...........	734.80	....	....	82.22	652.58	....
Solids in urine...........	42.60	9.95	9.02	2.57	8.54	12.52
Water of respiration[1].....	1060.53	....	....	118.67	941.86	....
Carbon dioxide...........	640.27	....	174.63	....	465.64	....
Total..................	2478.20	9.95	183.65	203.46	2068.62	12.52
Loss..................	1849.65	9.95	183.65	203.46	1440.07	12.52
EXPERIMENT No. 81. A.H.M.						
First day, Nov. 21, 1905.						
Income: Oxygen from air....	516.78	....	....	....	516.78	....
Outgo:						
Water in urine...........	621.26	....	....	69.52	551.74	....
Solids in urine...........	38.74	9.11	7.52	2.18	7.32	12.61
Water of respiration[1].....	608.59	....	....	68.10	540.49	....
Carbon dioxide...........	534.68	....	145.82	....	388.86	....
Total..................	1803.27	9.11	153.34	139.80	1488.41	12.61
Loss..................	1286.49	9.11	153.34	139.80	971.63	12.61

[1] Includes also water of perspiration.

TABLE 168.—*Elements katabolized in body*—Continued.

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
EXPERIMENT 81. A.H.M. (cont.)						
Second day, Nov. 22, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air	527.06	....	....	....	527.06	....
Outgo:						
Water in urine	783.16	....	....	87.64	695.52	....
Solids in urine	48.04	13.05	9.48	2.91	11.38	11.22
Water of respiration[1]	670.74	....	....	75.06	595.68	....
Carbon dioxide	524.33	....	142.98	....	381.35	....
Total	2026.27	13.05	152.46	165.61	1683.93	11.22
Loss	1499.21	13.05	152.46	165.61	1156.87	11.22
EXPERIMENT No. 82. H.C.K.						
First day, Nov. 24, 1905.						
Income: Oxygen from air	663.26	....	....	....	663.26	....
Outgo:						
Water in urine	538.57	....	....	60.27	478.30	....
Solids in urine	37.13	9.38	7.71	2.07	8.30	9.67
Water of respiration[1]	842.10	....	....	94.23	747.87	....
Carbon dioxide	740.87	....	202.04	....	538.83	....
Total	2158.67	9.38	209.75	156.57	1773.30	9.67
Loss	1495.41	9.38	209.75	156.57	1110.04	9.67
Second day, Nov. 25, 1905.						
Income: Oxygen from air	733.77	....	....	....	733.77	....
Outgo:						
Water in urine	1740.07	....	....	194.71	1545.36	....
Solids in urine	54.93	14.36	10.77	3.59	9.88	16.33
Water of respiration[1]	940.50	....	....	105.24	835.26	....
Carbon dioxide	767.26	....	209.25	....	558.01	....
Total	3502.76	14.36	220.02	303.54	2948.51	16.33
Loss	2768.99	14.36	220.02	303.54	2214.74	16.33
EXPERIMENT No. 83. H.R.D.						
First day, Dec. 5, 1905.						
Income: Oxygen from air	585.22	....	....	....	585.22	....
Outgo:						
Water in urine	1159.21	....	....	129.72	1029.49	....
Solids in urine	45.29	13.25	9.76	2.65	11.44	8.19
Water of respiration[1]	684.52	....	....	76.60	607.92	....
Carbon dioxide	606.70	....	165.47	....	441.23	....
Total	2495.72	13.25	175.23	208.97	2090.08	8.19
Loss	1910.50	13.25	175.23	208.97	1504.86	8.19
Second day, Dec. 6, 1905.						
Income: Oxygen from air	554.37	....	....	....	554.37	....
Outgo:						
Water in urine	1012.39	....	....	113.29	899.10	....
Solids in urine	52.61	13.53	12.78	3.20	14.37	8.73
Water of respiration[1]	672.01	....	....	75.20	596.81	....
Carbon dioxide	579.17	....	157.95	....	421.22	....
Total	2316.18	13.53	170.73	191.69	1931.50	8.73
Loss	1761.81	13.53	170.73	191.69	1377.13	8.73

[1] Includes also water of perspiration.

TABLE 168.—*Elements katabolized in body*—Continued.

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
EXPERIMENT No. 85. N.M.P.						
First day, Dec. 9, 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Income: Oxygen from air....	627.54	....	....	....	627.54	....
Outgo:						
Water in urine...........	[2] 1178.48	....	....	[2] 131.87	[2] 1046.61	....
Solids in urine...........	[2] 44.14	[3] 11.37	[2] 7.70	[2] 1.96	[2] 10.28	[2] 12.83
Water of respiration [1].....	775.79	....	....	86.81	688.98	....
Carbon dioxide...........	696.59	....	189.96	....	506.63	....
Total..................	2695.00	11.37	197.66	220.64	2252.50	12.83
Loss	2067.46	11.37	197.66	220.64	1624.96	12.83
Second day, Dec. 10, 1905.						
Income: Oxygen from air....	675.57	....	....	....	657.57	....
Outgo:						
Water in urine...........	642.44	....	....	71.89	570.55	....
Solids in urine...........	36.96	11.35	8.22	2.11	9.71	5.57
Water of respiration [1].....	813.43	....	....	91.02	722.41	....
Carbon dioxide...........	719.33	....	196.18	....	523.15	....
Total..................	2212.16	11.35	204.40	165.02	1825.82	5.57
Loss...................	1536.59	11.35	204.40	165.02	1150.25	5.57
EXPERIMENT No. 89. D.W.						
First day, Jan. 10, 1906.						
Income: Oxygen from air....	645.36	....	....	....	645.36	....
Outgo:						
Water in urine...........	599.55	....	....	67.09	532.46	....
Solids in urine...........	44.85	9.99	8.38	2.26	10.88	13.34
Water of respiration [1].....	819.57	....	....	91.71	727.86	....
Carbon dioxide...........	722.40	....	197.01	....	525.39	....
Total..................	2186.37	9.99	205.39	161.06	1796.59	13.34
Loss...................	1541.01	9.99	205.39	161.06	1151.23	13.34
Second day, Jan. 11, 1906.						
Income: Oxygen from air....	681.32	....	....	....	681.32	....
Outgo:						
Water in urine...........	492.22	....	....	55.08	437.14	....
Solids in urine...........	47.38	14.46	9.87	2.81	12.79	7.45
Water of respiration [1].....	802.74	....	....	89.83	712.91	....
Carbon dioxide...........	705.54	....	192.43	....	513.11	....
Total..................	2047.88	14.46	202.30	147.72	1675.95	7.45
Loss...................	1366.56	14.46	202.30	147.72	994.63	7.45

[1] Includes also water of perspiration.
[2] Includes estimated portion in urine lost. See p. 243.
[3] Includes 0.32 gram nitrogen determined in urine lost.

Materials katabolized in body.—Table 169 shows the amounts of body protein, fat, and glycogen derived by formulæ from the quantities of the elements katabolized as shown in table 168.

Balance of water.—The amounts of preformed water lost from the body by the several subjects of these experiments, together with the water of oxidation of organic hydrogen are shown in table 170. From this table the sources of intake and output of water may also be found. The method of obtaining the data has already been explained.

TABLE 169.—*Materials katabolized in body—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	(a) Water.	(b) Protein.	(c) Fat.	(d) Carbohydrates (as glycogen).	(e) Ash.
Experiment No. 79. H. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Oct. 13-14, 1905	1443.52	48.66	132.58	117.55	8.78
Oct. 14-15, 1905	1299.01	86.10	158.17	39.95	11.17
Experiment No. 80. C. R. Y.:					
Oct. 27-28, 1905	1815.23	46.68	141.58	103.62	18.93
Oct. 28-29, 1905	1571.11	59.70	190.09	17.14	12.52
Experiment No. 81. A. H. M.:					
Nov. 21-22, 1905	1044.41	54.66	146.93	28.72	12.61
Nov. 22-23, 1905	1275.44	78.30	161.17	[1] 25.72	11.22
Experiment No. 82. H. C. K.:					
Nov. 24-25, 1905	1124.60	56.28	140.10	165.56	9.67
Nov. 25-26, 1905	2419.54	86.16	203.56	44.72	16.83
Experiment No. 83. H. R. D.:					
Dec. 5-6, 1905	1635.07	79.50	156.18	32.78	8.19
Dec. 6-7, 1905	1487.61	81.18	143.93	41.60	8.73
Experiment No. 85. N. M. P.:					
Dec. 9-10, 1905 [2]	1714.01	68.22	127.42	146.02	12.83
Dec. 10-11, 1905	1204.32	68.10	168.00	91.64	5.57
Experiment No. 89. D. W.:					
Jan. 10-11, 1906	1171.22	59.94	131.80	165.63	13.34
Jan. 11-12, 1906	1051.44	86.76	182.61	39.63	7.45

[1] Glycogen gained.
[2] Amounts for first day, Dec. 9-10, are calculated, with elements of estimated urine lost included. See p. 243.

TABLE 170.—*Distribution of intake and outgo of water—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	Outgo from the body.			Balance of preformed water.			(g) Water of oxidation of organic hydrogen (c—d).
	(a) Water of urine.	(b) Water of respiration and perspiration.	(c) Total (a+b).	(d) Preformed (katabolized) water in outgo.	(e) Intake in drink.	(f) Loss of preformed water (d—e).	
No. 79. H.E.S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Oct. 13-14, 1905	996.1	667.0	1663.1	1443.5	782.5	661.0	219.6
Oct. 14-15, 1905	809.9	704.1	1514.0	1299.0	339.9	959.1	215.0
No. 80. C.R.Y.:							
Oct. 27-28, 1905	1105.7	926.8	2032.5	1815.2	132.8	1682.4	217.3
Oct. 28-29, 1905	734.8	1060.5	1795.3	1571.1	206.4	1364.7	224.2
No. 81. A.H.M.:							
Nov. 21-22, 1905	621.3	608.6	1229.9	1044.4	291.1	753.3	185.5
Nov. 22-23, 1905	783.2	670.7	1453.9	1275.4	193.8	1081.6	178.5
No. 82. H.C.K.:							
Nov. 24-25, 1905	538.6	842.1	1380.7	1124.7	857.8	266.9	256.0
Nov. 25-26, 1905	1740.1	940.5	2680.6	[1] 2419.5	1092.9	[1] 1326.6	261.1
No. 83. H.R.D.:							
Dec. 5-6, 1905	1159.2	684.5	1843.7	1635.1	1467.1	168.0	208.6
Dec. 6-7, 1905	1012.4	672.0	1684.4	1487.6	884.2	603.4	196.8
No. 85. N.M.P.:							
Dec. 9-10, 1905	1178.5	775.8	1954.3	1714.0	704.5	1009.5	240.3
Dec. 10-11, 1905	642.4	813.4	1455.8	1204.3	707.7	496.6	251.5
No. 89. D.W.:							
Jan. 10-11, 1906	599.5	819.6	1419.1	1171.2	115.1	1056.1	247.9
Jan. 11-12, 1906	492.2	802.7	1294.9	1051.4	357.2	694.2	243.5

[1] Does not include water of feces passed on this day. See p. 120.

CHANGES IN BODY-WEIGHT COMPARED WITH BALANCE OF INCOME AND OUTGO.

In table 171 the changes of body-weight obtained by weighing the subjects each morning are compared with the losses of body material, i. e., the determined weights of the different factors of the outgo less those of the income.

Although the comparisons in table 171 do not show exact balances, nevertheless, they are in general fairly satisfactory and for the most part there is a

TABLE 171.—*Comparison of changes in body weight with balance of income and outgo—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	Income.			Outgo.					
	(*a*) Water consumed.	(*b*) Oxygen.	(*c*) Total (*a*+*b*).	(*d*) Urine.[1]	(*e*) Carbon dioxide.	(*f*) Water of respiration and perspiration.	(*g*) Total (*d*+*e*+*f*).	(*h*) Loss of body material (*c*−*g*).	(*i*) Loss of body-weight.
No. 79. H.E.S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Oct. 13–14, 1905.	782.50	575.90	1358.40	1018.10	632.02	666.98	2317.10	958.70	1089.00
Oct. 14–15, 1905.	339.90	605.27	945.17	883.90	635.18	704.07	2223.15	1277.98	1258.00
No. 80. C.R.Y.:									
Oct. 27–28, 1905.	132.80	576.21	709.01	879.20	627.38	926.76	2433.34	1724.33	1725.00
Oct. 28–29, 1905.	206.40	628.55	834.95	1103.80	640.27	1060.53	2804.60	1969.65	1935.00
No. 81. A.H.M.:									
Nov. 21–22, 1905.	291.10	516.78	807.88	621.70	534.68	608.59	1764.97	957.09	969.00
Nov. 22–23, 1905.	193.80	527.06	720.86	787.90	524.33	670.74	1982.97	1262.11	1237.00
No. 82. H.C.K.:									
Nov. 24–25, 1905.	857.80	663.26	1521.06	559.40	740.87	842.10	2142.37	621.31	605.00
Nov. 25–26, 1905.	1092.90	733.77	1826.67	1632.20	767.26	940.50	[2] 3339.96	1513.29	1528.00
No. 83. H.R.D.:									
Dec. 5–6, 1905.	1467.10	585.22	2052.32	1295.80	606.70	684.52	2587.02	534.70	539.00
Dec. 6–7, 1905.	884.20	554.37	1438.57	1070.90	579.17	672.01	2322.08	883.51	864.00
No. 85. N.M.P.:									
Dec. 9–10, 1905.	704.50	627.54	1332.04	[3] 1379.72	696.59	775.79	2852.10	1520.06	1498.00
Dec. 10–11, 1905.	707.70	675.57	1383.27	670.80	719.33	813.43	2203.56	820.29	830.00
No. 89. D.W.:									
Jan. 10–11, 1906.	115.10	645.36	760.46	749.05	722.40	819.57	2291.02	1530.56	1502.00
Jan. 11–12, 1906.	357.20	681.32	1038.52	494.70	705.54	802.74	2002.98	964.46	980.00

[1] The data in this column should not be confounded with urine data in other tables. See explanation, p. 66.
[2] On Nov. 25, 118.0 grams of feces were excreted. This amount is not included in the total outgo. See p. 120.
[3] Includes 34.62 grams urine calculated as lost. See p. 243.

tendency for the errors in the individual days of each experiment to compensate each other. A particularly poor balance was obtained on the first day of experiment No. 79, the reason for which is not known. The average error in terms of the calculated loss is for experiment No. 79, +55 grams or +4.9 per cent of the average daily loss; for experiment No. 80, —17 grams or —0.9 per cent; for experiment No. 81, —7 grams or —0.6 per cent; for experiment No. 82, —1 gram or —0.1 per cent; for exp. No. 83, —8 grams, or —1.1 per cent; for exp. No. 85, —6 grams or —0.5 per cent; for exp. No. 89, —7 grams or —0.6 per cent. The wide variation in exp. No. 79 is of course due to the large error, 130 grams, on the first day. In all but two experiments the larger loss of body-weight occurred on the second day.

OUTPUT OF HEAT.

The total heat production per period and per day for this series of experiments is shown in column *d* of table 172. Columns *a, b,* and *c* contain the data essential to obtaining column *d*.

TABLE 172.—*Summary of calorimetric measurements and total heat production—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	Period.	(*a*) Heat measured in terms C_{20}.	(*b*) Heat used in vaporization of water.	(*c*) Sum of heat corrections.[1]	(*d*) Total heat production (*a*+*b*+*c*).
79. H. E. S. 1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Oct. 13-14..	7 a. m. to 9 a. m..	158.8	32.2	−17.9	173.1
	9 a. m. 11 a. m..	130.0	33.7	+ .5	164.2
	11 a. m. 1 p. m..	136.9	33.7	+18.3	188.9
	1 p. m. 3 p. m..	136.9	33.8	−15.5	155.2
	3 p. m. 5 p. m..	113.7	33.3	+27.1	174.1
	5 p. m. 7 p. m..	117.6	33.8	− 8.7	142.7
	7 p. m. 9 p. m..	114.4	32.1	+ 2.3	148.8
	9 p. m. 11 p. m..	136.6	33.0	− 2.4	167.2
	11 p. m. 1 a. m..	109.7	32.9	+34.0	176.6
	1 a. m. 3 a. m..	139.2	38.1	−19.1	158.2
	3 a. m. 5 a. m..	101.9	32.9	+12.9	147.7
	5 a. m. 7 a. m..	117.0	35.4	+ 2.3	154.7
	Total.............	1512.7	404.9	+33.8	1951.4
Oct. 14-15..	7 a. m. to 9 a. m..	199.1	33.0	−44.6	187.5
	9 a. m. 11 a. m..	155.9	34.4	−27.2	163.1
	11 a. m. 1 p. m..	125.9	38.2	+16.7	180.8
	1 p. m. 3 p. m..	141.2	34.6	+ 3.3	179.1
	3 p. m. 5 p. m..	125.1	35.2	− 1.4	158.9
	5 p. m. 7 p. m..	138.0	35.8	+13.2	187.0
	7 p. m. 9 p. m..	133.8	36.6	+ 8.3	178.7
	9 p. m. 11 p. m..	120.9	36.7	−21.4	136.2
	11 p. m. 1 a. m..	119.1	35.7	+34.3	189.1
	1 a. m. 3 a. m..	141.3	36.4	− 3.0	174.7
	3 a. m. 5 a. m..	134.1	32.4	−16.1	150.4
	5 a. m. 7 a. m..	118.3	31.8	+11.4	161.5
	Total..............	1652.7	420.8	−26.5	2047.0
80. C. R. Y.	Preliminary:				
Oct. 26-27..	11 p. m. to 1 a. m..	101.2	39.1	[2]+12.6	[2]152.9
	1 a. m. 3 a. m..	99.6	49.3	....	[2]148.9
	3 a. m. 5 a. m..	96.0	45.5	[2]+ 8.4	[2]149.9
	5 a. m. 7 a. m..	91.2	44.8	[2]−24.0	[2]112.0
	Total, 8 hours......	388.0	178.7	[2]− 3.0	[2]563.7
Oct. 27-28..	7 a. m. to 9 a. m..	191.2	40.6	−17.5	214.3
	9 a. m. 11 a. m..	161.8	29.0	−19.3	171.5
	11 a. m. 1 p. m..	113.7	50.7	−22.3	142.1
	1 p. m. 3 p. m..	92.9	44.9	− 4.4	133.4
	3 p. m. 5 p. m..	97.2	45.7	+38.6	181.5
	5 p. m. 7 p. m..	100.1	45.9	−11.7	134.3
	7 p. m. 9 p. m..	110.1	42.4	− 5.5	147.0
	9 p. m. 11 p. m..	109.3	42.9	+ 1.7	153.9
	11 p. m. 1 a. m..	107.0	44.3	+41.3	192.6
	1 a. m. 3 a. m..	101.7	57.2	− 3.1	155.8
	3 a. m. 5 a. m..	99.0	53.3	+ 9.1	161.4
	5 a. m. 7 a. m..	97.6	62.3	+ 6.4	166.3
	Total.............	1381.6	559.2	+13.3	1954.1

[1] See pp. 42-49. [2] Does not include correction for change in body temperature.

TABLE 172.—*Summary of calorimetric measurements and total heat production*—Continued.

Experiment number, subject, and date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
80. C.R.Y. (cont. 1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Oct. 28–29..	7 a. m. to 9 a. m..	193.2	54.6	+33.0	280.8
	9 a. m. 11 a. m..	145.9	45.8	−20.1	171.6
	11 a. m. 1 p. m..	97.4	52.1	− 9.6	139.9
	1 p. m. 3 p. m..	101.4	56.4	+12.0	169.8
	3 p. m. 5 p. m..	108.3	53.0	+13.8	175.1
	5 p. m. 7 p. m..	132.4	54.4	− 0.3	186.5
	7 p. m. 9 p. m..	116.8	49.1	−11.2	154.7
	9 p. m. 11 p. m..	118.4	49.3	+ 2.6	170.3
	11 p. m. 1 a. m..	113.5	56.4	− 8.9	161.0
	1 a. m. 3 a. m..	105.2	55.0	− 6.3	153.9
	3 a. m. 5 a. m..	121.1	50.4	−11.5	160.0
	5 a. m. 7 a. m..	115.5	51.4	+ 9.0	175.9
	Total..............	1469.1	627.9	+ 2.5	2099.5
81. A. H. M.	Preliminary:				
Nov. 20–21..	1 a. m. to 3 a. m..	70.3	35.5	[2]− 3.6	[2]105.2
	3 a. m. 5 a. m..	69.3	33.0	[2]+ 6.0	[2]108.2
	5 a. m. 7 a. m..	65.9	31.9	[2]+ 9.6	[2]107.5
	Total, 6 hours......	208.5	100.4	[2]+12.0	[2]320.9
Nov. 21–22..	7 a. m. to 9 a. m..	150.4	35.6	− 3.8	182.2
	9 a. m. 11 a. m..	135.2	39.9	−25.4	149.7
	11 a. m. 1 p. m.	130.0	34.7	−10.7	154.0
	1 p. m. 3 p. m..	110.2	33.0	+43.9	187.1
	3 p. m. 5 p. m..	130.6	32.9	−23.5	140.1
	5 p. m. 7 p. m..	120.3	33.5	+10.7	164.5
	7 p. m. 9 p. m..	119.5	31.0	−10.2	140.3
	9 p. m. 11 p. m..	122.6	28.2	−17.3	133.5
	11 p. m. 1 a. m..	65.0	29.9	+27.1	122.0
	1 a. m. 3 a. m..	70.4	29.3	+ 2.8	102.5
	3 a. m. 5 a. m..	84.9	29.1	−12.4	101.7
	5 a. m. 7 a. m..	72.3	31.4	+47.2	150.9
	Total	1311.4	388.7	+28.4	1728.5
Nov. 22–23..	7 a. m. to 9 a. m..	171.0	33.7	−26.1	178.6
	9 a. m. 11 a. m..	154.1	38.3	− 7.7	184.7
	11 a. m. 1 p. m..	149.8	32.8	− 5.8	176.8
	1.p. m. 3 p. m..	89.7	30.4	− 8.5	111.6
	3 p. m. 5 p. m..	68.9	29.6	+22.9	121.4
	5 p. m. 7 p. m..	126.2	34.7	+18.5	179.3
	7 p. m. 9 p. m..	106.5	33.6	−23.7	116.5
	9 p. m. 11 p. m..	120.6	34.3	+ 2.7	157.7
	11 p. m. 1 a. m..	97.3	32.9	+23.3	153.6
	1 a. m. 3 a. m..	93.8	33.2	+ 5.8	132.8
	3 a. m. 5 a. m..	93.0	32.6	− 4.5	121.1
	5 a. m. 7 a. m..	99.0	33.7	+13.9	146.6
	Total..............	1369.9	399.8	+10.8	1780.5

[1] See pp. 42-49. [2] Does not include correction for change in body temperature.

TABLE 172.—*Summary of calorimetric measurements and total heat production*—Continued.

Experiment number, subject, and date.	Period.	(a) Heat measured in terms C_{30}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
82. H. C. K.					
1906.	Preliminary:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Nov. 23–24..	7 p. m. to 9 p. m..	168.9	43.7	[2]− 6.0	[2] 206.6
	9 p. m. 11 p. m..	168.8	40.0	[2]− 1.2	[2] 207.6
	11 p. m. 1 a. m..	117.0	41.2	[2]+11.4	[2] 169.6
	1 a. m. 3 a. m..	89.3	38.2	[2]− 6.0	[2] 121.5
	3 a. m. 5 a. m..	93.7	38.6	[2]+ 6.0	[2] 138.3
	5 a. m. 7 a. m..	116.2	45.6	[2]− 5.4	[2] 156.4
	Total, 12 hours.....	753.9	247.3	[2]− 1.2	[2]1000.0
Nov. 24–25..	7 a. m. to 9 a. m..	210.7	59.3	−19.8	250.2
	9 a. m. 11 a. m..	167.6	52.0	+21.8	241.4
	11 a. m. 1 p. m..	165.8	35.9	−51.2	150.5
	1 p. m. 3 p. m..	164.8	43.6	+ 7.4	215.8
	3 p. m. 5 p. m..	111.4	44.2	− 9.5	146.1
	5 p. m. 7 p. m..	117.7	40.5	+ 7.7	165.9
	7 p. m. 9 p. m..	172.1	42.3	+10.5	224.9
	9 p. m. 11 p. m..	169.0	39.2	− 8.6	199.6
	11 p. m. 1 a. m..	101.0	38.9	+20.3	160.2
	1 a. m. 3 a. m..	122.2	30.3	− 7.2	145.3
	3 a. m. 5 a. m..	105.8	38.1	+20.3	164.2
	5 a. m. 7 a. m..	106.6	40.2	+10.7	157.5
	Total.............	1714.7	504.5	+ 2.4	2221.6
Nov. 25–26..	7 a. m. to 9 a. m..	235.6	64.1	−28.9	270.8
	9 a. m. 11 a. m..	171.4	49.6	−12.7	208.3
	11 a. m. 1 p. m..	165.9	45.2	+18.9	230.0
	1 p. m. 3 p. m..	161.0	43.7	− 7.9	196.8
	3 p. m. 5 p. m..	135.5	42.8	+10.2	188.5
	5 p. m. 7 p. m..	173.3	42.6	+ 6.2	222.1
	7 p. m. 9 p. m..	192.2	48.7	+15.8	256.7
	9 p. m. 11 p. m..	191.0	46.3	−12.0	225.3
	11 p. m. 1 a. m..	108.2	42.0	+ 2.5	152.7
	1 a. m. 3 a. m..	111.7	33.0	+18.2	162.9
	3 a. m. 5 a. m..	130.4	40.0	+ 3.8	174.2
	5 a. m. 7 a. m..	128.7	44.6	+15.6	188.9
	Total..............	1904.9	542.6	+29.7	2477.2
83. H. R. D.	Preliminary:				
Dec. 5......	11 p. m. to 1 a. m..	94.9	45.7	[2]− 3.6	[2] 137.0
	1 a. m. 3 a. m..	89.7	43.2	[2]− 4.8	[2] 128.1
	3 a. m. 5 a. m..	85.2	36.9	[2]+ 1.2	[2] 123.3
	5 a. m. 7 a. m..	80.6	35.7	[2]+ 2.4	[2] 118.7
	Total, 8 hours.......	350.4	161.5	[2]− 4.8	[2] 507.1

[1] See pp. 42-49. [2] Does not include correction for change in body temperature.

TABLE 172.—*Summary of calorimetric measurements and total heat production*—Continued.

Experiment number, subject, and date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
83. H. R. D. (cont. 1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Dec. 5–6...	7 a. m. to 9 a. m..	174.4	42.5	− 7.4	209.5
	9 a. m. 11 a. m..	131.4	36.2	+ 4.1	171.7
	11 a. m. 1 p. m..	159.4	36.5	−11.3	184.6
	1 p. m. 3 p. m..	106.9	33.7	−12.9	127.7
	3 p. m. 5 p. m..	120.1	32.8	− 6.4	146.5
	5 p. m. 7 p. m..	68.0	38.0	+ 6.6	112.6
	7 p. m. 9 p. m..	176.0	36.9	+10.0	222.9
	9 p. m. 11 p. m..	119.7	33.4	− 2.9	150.2
	11 p. m. 1 a. m..	97.8	33.7	+31.9	163.4
	1 a. m. 3 a. m..	101.2	38.4	− 5.5	134.1
	3 a. m. 5 a. m..	88.7	33.7	+14.5	136.9
	5 a. m. 7 a. m..	106.2	35.5	+11.8	153.5
	Total.............	1449.8	431.3	+32.5	1913.6
Dec. 6–7...	7 a. m. to 9 a. m..	201.4	47.3	−28.0	220.7
	9 a. m. 11 a. m..	104.0	31.8	− 5.9	129.9
	11 a. m. 1 p. m..	186.0	36.1	+13.2	235.3
	1 p. m. 3 p. m..	83.6	31.6	− 1.7	113.5
	3 p. m. 5 p. m..	129.3	33.0	+ 6.1	168.4
	5 p. m. 7 p. m..	103.7	32.5	− 7.7	128.5
	7 p. m. 9 p. m..	182.2	35.0	−14.8	202.4
	9 p. m. 11 p. m..	90.6	32.4	−10.5	112.5
	11 p. m. 1 a. m..	98.7	33.4	+31.8	163.9
	1 a. m. 3 a. m..	114.9	31.3	− 5.0	141.2
	3 a. m. 5 a. m..	85.6	29.1	+13.0	127.7
	5 a. m. 7 a. m..	116.3	32.0	+14.5	162.8
	Total.............	1496.3	405.5	+ 5.0	1906.8
85. N. M. P.	Preliminary:				
Dec. 9.....	11 p. m. to 1 a. m..	123.8	41.5	[2]+ 6.0	[2]171.3
	1 a. m. 3 a. m..	134.5	36.0	[2]− 5.4	[2]165.1
	3 a. m. 5 a. m..	99.2	34.9	[2]+ 7.8	[2]141.9
	5 a. m. 7 a. m..	89.7	34.2	[2]+ 3.0	[2]126.9
	Total, 8 hours	447.2	146.6	[2]+11.4	[2]605.2
Dec. 9–10..	7 a. m. to 9 a. m..	202.6	43.6	−28.6	217.6
	9 a. m. 11 a. m..	158.3	38.6	− 0.4	196.5
	11 a. m. 1 p. m..	156.1	37.5	−13.4	180.2
	1 p. m. 3 p. m..	112.0	33.4	+ 7.4	152.8
	3 p. m. 5 p. m..	132.7	33.4	+26.5	192.6
	5 p. m. 7 p. m..	121.6	36.8	+ 1.6	160.0
	7 p. m. 9 p. m..	180.1	41.7	+ 4.9	226.7
	9 p. m. 11 p. m..	150.8	34.4	−23.2	162.0
	11 p. m. 1 a. m..	93.8	35.3	+16.6	145.7
	1 a. m. 3 a. m..	131.6	33.7	− 7.7	157.6
	3 a. m. 5 a. m..	104.5	33.6	+19.7	157.8
	5 a. m. 7 a. m..	104.3	34.8	+20.2	159.3
	Total.............	1648.4	436.8	+23.6	2108.8

[1] See pp. 42-49. [2] Does not include correction for change in body temperature.

TABLE 172.—*Summary of calorimetric measurements and total heat production*—Continued.

Experiment number, subject, and date.	Period.	(a) Heat measured in terms C_{20}.	(b) Heat used in vaporization of water.	(c) Sum of heat corrections.[1]	(d) Total heat production (a+b+c).
85. N.M.P. (cont.) 1905.		*Calories.*	*Calories.*	*Calories.*	*Calories.*
Dec. 10–11..	7 a. m. to 9 a. m..	216.0	44.0	−29.0	231.0
	9 a. m. 11 a. m..	162.8	37.9	− 0.5	200.2
	11 a. m. 1 p. m..	161.5	39.2	+ 6.5	207.2
	1 p. m. 3 p. m..	150.6	36.6	+11.6	198.8
	3 p. m. 5 p. m..	110.1	35.8	+20.6	166.5
	5 p. m. 7 p. m..	144.5	41.0	+ 9.1	194.6
	7 p. m. 9 p. m..	185.4	41.9	+ 3.6	230.9
	9 p. m. 11 p. m..	158.4	41.1	−15.3	184.2
	11 p. m. 1 a. m..	109.0	40.6	+27.9	177.5
	1 a. m. 3 a. m..	132.4	43.5	− 2.8	173.1
	3 a. m. 5 a. m..	114.3	40.5	+ 8.0	162.8
	5 a. m. 7 a. m..	127.7	43.6	+ 6.6	177.9
	Total..............	1772.7	485.7	+46.3	2304.7
89. D. W. 1906.	Preliminary:				
Jan. 9......	11 p. m. to 1 a. m..	102.7	44.6	[2]+10.8	[2]158.1
	1 a. m. 3 a. m..	128.9	44.4	[2]+ 3.6	[2]177.0
	3 a. m. 5 a. m..	121.8	46.1	[2]−10.8	[2]157.1
	5 a. m. 7 a. m..	101.8	42.4	[2]+ 7.2	[2]151.4
	Total, 8 hours	455.3	177.5	[2]+10.8	[2]643.6
Jan. 10–11..	7 a. m. to 9 a. m..	207.8	40.7	−17.3	231.2
	9 a. m. 11 a. m..	100.5	38.5	−28.9	110.1
	11 a. m. 1 p. m..	97.4	39.6	+ 2.2	139.2
	1 p. m. 3 p. m..	186.5	42.5	+27.0	256.0
	3 p. m. 5 p. m..	89.9	38.7	−19.9	108.7
	5 p. m. 7 p. m..	180.0	42.6	+19.0	241.6
	7 p. m. 9 p. m..	141.4	43.4	− 2.6	182.2
	9 p. m. 11 p. m..	211.1	43.8	−18.0	236.9
	11 p. m. 1 a. m..	91.3	41.4	+19.5	152.2
	1 a. m. 3 a. m..	134.2	38.1	−18.3	154.0
	3 a. m. 5 a. m..	117.8	40.7	+16.5	175.0
	5 a. m. 7 a. m..	118.6	40.8	+ 3.6	163.0
	Total..............	1676.5	490.8	−17.2	2150.1
Jan. 11–12..	7 a. m. to 9 a. m..	204.9	38.9	+ 1.3	245.1
	9 a. m. 11 a. m..	101.5	36.2	−18.6	119.1
	11 a. m. 1 p. m..	118.4	40.5	+ 7.3	166.2
	1 p. m. 3 p. m..	208.7	38.2	+17.5	264.4
	3 p. m. 5 p. m..	87.7	36.7	−13.1	111.3
	5 p. m. 7 p. m..	202.0	43.7	+ 9.0	254.7
	7 p. m. 9 p. m..	151.9	47.4	+ 1.1	200.4
	9 p. m. 11 p. m..	204.0	41.0	−10.5	234.5
	11 p. m. 1 a. m..	102.3	41.4	+47.6	191.3
	1 a. m. 3 a. m..	139.9	36.5	−42.8	133.6
	3 a. m. 5 a. m..	131.2	38.0	− 1.0	168.2
	5 a. m. 7 a. m..	108.8	36.9	+19.8	165.5
	Total..............	1761.3	475.4	+17.6	2254.3

[1] See pp. 42-49. [2] Does not include correction for change in body temperature.

BALANCE OF ENERGY.

The comparison between the total heat production as measured and the completed energy of katabolized body material is given in table 173.

TABLE 173.—*Comparison of energy derived from katabolized body material with total heat production—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	Energy derived from different sources.						(g) Total heat production.	Energy from body material greater (+) or less (−) than output.	
	From body protein.								
	(a) Energy of protein katabolized.	(b) Potential energy of urine.	(c) Net energy (a−b).	(d) From body fat.	(e) From body glycogen.	(f) Total (c+d+e).		(h) Amount (f−g).	(i) Proportion (h÷g).
No. 79. H.E.S.:	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*
Oct. 13–14, 1905.	275	72	203	1265	493	1961	1951	+10	+0.5
Oct. 14–15, 1905.	486	116	370	1509	167	2046	2047	− 1	....
No. 80. C.R.Y.:									
Oct. 27–28, 1905.	264	75	189	1351	434	1974	1954	+20	+1.0
Oct. 28–29, 1905.	337	97	240	1813	72	2125	2099	+26	+1.2
No. 81. A.H.M.:									
Nov. 21–22, 1905.	309	80	229	1402	120	1751	1729	+22	+1.3
Nov. 22–23, 1905.	442	109	333	1538	[1] 108	1763	1781	−18	−1.0
No. 82. H.C.K.:									
Nov. 24–25, 1905.	318	88	230	1337	694	2261	2222	+39	+1.8
Nov. 25–26, 1905.	487	122	365	1942	187	2494	2477	+17	+0.7
No. 83. H.R.D.:									
Dec. 5–6, 1905.	449	116	333	1490	137	1960	1914	+46	+2.4
Dec. 6–7, 1905.	459	151	308	1373	174	1855	1907	−52	−2.7
No. 85. N.M.P.:									
Dec. 9–10, 1905.	385	96	289	1216	612	2117	2109	+ 8	+0.4
Dec. 10–11, 1905.	385	99	286	1603	384	2273	2305	−32	−1.4
No. 89. D.W.:									
Jan. 10–11, 1906.	339	93	246	1257	694	2197	2150	+47	+2.2
Jan. 11–12, 1906.	490	114	376	1742	166	2284	2254	+30	+1.3

[1] Glycogen gained.

The average discrepancy for each experiment is as follows: Experiment No. 79, +5 calories or +0.3 per cent; for experiment No. 80, +23 calories or +1.1 per cent; experiment No. 81, +2 calories or +0.1 per cent; experiment No. 82, +28 calories or +1.2 per cent; experiment No. 83, —3 calories or —0.2 per cent; experiment No. 85, —12 calories or —0.5 per cent; experiment No. 89, +39 calories or +1.8 per cent. Average of 7 experiments +12 calories or +0.5 per cent.

RELATIONS BETWEEN OXYGEN CONSUMPTION, CARBON DIOXIDE ELIMINATION, AND HEAT PRODUCTION.

The oxygen and carbon dioxide thermal quotients and the respiratory quotients for experiments Nos. 79-83, 85, and 89 are shown in table 174.

TABLE 174.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients—Metabolism experiments Nos. 79-83, 85, and 89.*

Experiment number, subject, and date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b ÷ a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d ÷ a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f ÷ g).
79. H.E.S. 1905.		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Oct. 13–14.	7 a. m. to 9 a. m.	173.1	67.3	38.9	67.8	39.2	34.5	47.1	0.73
	9 a. m. 11 a. m.	164.2	42.7	26.0	54.2	33.0	27.6	29.9	.92
	11 a. m. 1 p. m	188.9	49.7	26.3	55.1	29.2	28.1	34.8	.81
	1 p. m. 3 p. m	155.2	48.5	31.2	57.4	37.0	29.2	33.9	.86
	3 p. m. 5 p. m.	174.1	47.9	27.5	50.7	29.1	25.8	33.6	.77
	5 p. m. 7 p. m.	142.7	49.6	34.7	51.7	36.2	26.3	34.7	.76
	7 p. m. 9 p. m.	148.8	42.0	28.2	50.4	33.9	25.7	29.4	.87
	9 p. m. 11 p. m.	167.2	52.0	31.1	51.2	30.6	26.1	36.4	.72
	11 p. m. 1 a. m.	176.6	41.8	23.7	50.9	28.9	25.9	29.2	.89
	1 a. m. 3 a. m.	158.2	51.3	32.4	52.0	32.9	26.5	35.9	.74
	3 a. m. 5 a. m.	147.7	36.7	24.9	43.4	29.4	22.1	25.7	.86
	5 a. m. 7 a. m.	154.7	46.4	30.0	47.2	30.5	24.0	32.5	.74
	Total...........	1951.4	575.9	29.5	632.0	32.4	321.8	403.1	0.80
Oct. 14–15.	7 a. m. to 9 a. m.	187.5	66.4	35.4	65.7	35.1	33.5	46.5	0.72
	9 a. m. 11 a. m.	163.1	45.2	27.7	54.9	33.6	27.9	31.6	.88
	11 a. m. 1 p. m.	180.7	53.2	29.4	54.1	29.9	27.5	37.2	.74
	1 p. m. 3 p. m.	179.1	55.0	30.7	56.3	31.5	28.7	38.5	.74
	3 p. m. 5 p. m.	158.9	51.5	32.4	51.3	32.3	26.1	36.0	.73
	5 p. m. 7 p. m.	187.0	46.9	25.1	54.6	29.2	27.8	32.8	.85
	7 p. m. 9 p. m.	178.7	52.4	29.3	56.8	31.8	28.9	36.7	.79
	9 p. m. 11 p. m.	136.2	47.8	35.1	45.3	33.3	23.1	33.5	.69
	11 p. m. 1 a. m.	189.1	51.8	27.4	51.3	27.1	26.1	36.3	.72
	1 a. m. 3 a. m.	174.7	48.8	27.9	52.1	29.8	26.5	34.2	.78
	3 a. m. 5 a. m.	150.5	43.4	28.8	45.5	30.2	23.1	30.4	.76
	5 a. m. 7 a. m.	161.5	42.9	26.6	47.3	29.3	24.1	30.0	.80
	Total...........	2047.0	605.3	29.6	635.2	31.0	323.3	423.7	0.76
80. C.R.Y. Oct. 27....	11 p. m. to 1 a. m.	[1] 152.9	32.2	21.1	61.6	40.3	31.4	22.6	1.39
	1 a. m. 3 a. m.	[1] 148.9	40.4	27.1	47.5	31.9	24.2	28.2	.86
	3 a. m. 5 a. m.	[1] 149.9	39.1	26.1	50.2	33.5	25.5	27.4	.93
	5 a. m. 7 a. m.	[1] 112.0	33.0	29.5	52.4	46.8	26.7	23.1	1.16
	Total, 8 hours....	[1] 563.7	144.7	25.7	211.7	37.6	107.8	101.3	1.06
Oct. 27–28.	7 a. m. to 9 a. m.	214.3	70.8	33.0	73.6	34.3	37.5	49.5	0.76
	9 a. m. 11 a. m.	171.5	43.9	25.6	58.7	34.2	29.9	30.8	.97
	11 a. m. 1 p. m.	142.1	46.3	32.6	55.2	38.9	28.1	32.4	.87
	1 p. m. 3 p. m.	133.4	39.2	29.4	49.0	36.8	25.0	27.5	.91
	3 p. m. 5 p. m.	181.5	50.8	28.0	51.3	28.2	26.1	35.6	.73
	5 p. m. 7 p. m.	134.3	44.0	32.7	46.2	34.4	23.5	30.8	.76
	7 p. m. 9 p. m.	147.0	42.2	28.7	43.3	29.5	22.0	29.6	.75
	9 p. m. 11 p. m.	153.9	40.3	26.2	43.6	28.4	22.2	28.2	.79
	11 p. m. 1 a. m.	192.6	55.8	29.0	58.7	30.5	29.9	39.0	.77
	1 a. m. 3 a. m.	155.8	43.7	28.0	47.0	30.2	23.9	30.6	.78
	3 a. m. 5 a. m.	161.4	51.8	32.1	50.7	31.4	25.8	36.2	.71
	5 a. m. 7 a. m.	166.3	47.4	28.5	50.0	30.1	25.5	33.2	.77
	Total...........	1954.1	576.2	29.5	627.3	32.1	319.4	403.4	0.79

[1] See p. 122.

TABLE 174.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Experiment number, subject, and date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
80. C.R.Y. (cont.) 1905.		Cals.	Grams.		Grams.		Liters.	Liters.	
Oct. 28–29.	7 a. m. to 9 a. m.	280.8	68.7	24.5	64.3	22.9	32.7	48.1	0.68
	9 a. m. 11 a. m.	171.6	48.1	28.0	55.0	32.0	28.0	33.7	.83
	11 a. m. 1 p. m.	139.9	46.6	33.3	49.5	35.4	25.2	32.6	.77
	1 p. m. 3 p. m.	169.8	53.2	31.4	52.0	30.6	26.5	37.3	.71
	3 p. m. 5 p. m.	175.1	49.6	28.3	48.3	27.6	24.6	34.7	.71
	5 p. m. 7 p. m.	186.5	59.5	31.9	56.5	30.3	28.8	41.7	.69
	7 p. m. 9 p. m.	154.7	48.8	31.5	51.6	33.3	26.3	34.1	.77
	9 p. m. 11 p. m.	170.3	44.1	25.9	49.3	28.9	25.1	30.9	.81
	11 p. m. 1 a. m.	161.0	59.0	36.7	57.0	35.4	29.0	41.3	.70
	1 a. m. 3 a. m.	153.9	43.7	28.4	47.7	31.0	24.2	30.6	.79
	3 a. m. 5 a. m.	160.0	53.7	33.6	52.5	32.9	26.7	37.6	.71
	5 a. m. 7 a. m.	175.9	53.5	30.4	56.6	32.2	28.8	37.4	.77
	Total...........	2099.5	628.5	29.9	640.3	30.5	325.9	440.0	0.74
81. A.H.M.	Preliminary:								
Nov. 21...	1 a. m. to 3 a. m.	[1] 105.2	28.1	26.7	34.7	33.0	17.7	19.7	0.90
	3 a. m. 5 a. m.	[1] 108.2	30.9	28.6	37.9	35.0	19.3	21.6	.89
	5 a. m. 7 a. m.	[1] 107.5	32.2	30.0	39.9	37.1	20.3	22.6	.90
	Total, 6 hours....	[1] 320.9	91.2	28.4	112.5	35.1	57.3	63.9	0.90
Nov. 21–22.	7 a. m. to 9 a. m.	182.2	52.6	28.9	61.6	33.8	31.4	36.8	0.85
	9 a. m. 11 a. m.	149.7	52.7	35.2	53.1	35.5	27.0	36.9	.73
	11 a. m. 1 p. m.	154.0	41.6	27.0	45.7	29.7	23.3	29.1	.80
	1 p. m. 3 p. m.	187.1	42.4	22.7	42.4	22.7	21.6	29.7	.73
	3 p. m. 5 p. m.	140.1	46.2	33.0	45.8	32.7	23.3	32.4	.72
	5 p. m. 7 p. m.	164.5	45.5	27.7	44.0	26.7	22.4	31.9	.70
	7 p. m. 9 p. m.	140.3	44.9	32.0	44.3	31.6	22.5	31.4	.72
	9 p. m. 11 p. m.	133.5	41.0	30.7	44.4	33.3	22.6	28.7	.79
	11 p. m. 1 a. m.	122.0	36.6	30.0	37.9	31.0	19.3	25.6	.75
	1 a. m. 3 a. m.	102.5	38.9	38.0	35.5	34.6	18.1	27.2	.66
	3 a. m. 5 a. m.	101.7	35.4	34.8	40.1	39.4	20.4	24.8	.82
	5 a. m. 7 a. m.	150.9	38.9	25.7	39.9	26.5	20.3	27.2	.75
	Total...........	1728.5	516.7	29.9	534.7	30.9	272.2	361.7	0.75
Nov. 22–23.	7 a. m. to 9 a. m.	178.6	62.3	34.9	59.7	33.4	30.4	43.6	0.70
	9 a. m. 11 a. m.	184.7	50.5	27.3	51.7	28.0	26.3	35.3	.75
	11 a. m. 1 p. m.	176.8	46.7	26.4	49.2	27.9	25.1	32.7	.77
	1 p. m. 3 p. m.	111.6	35.1	31.4	38.3	34.3	19.5	24.6	.79
	3 p. m. 5 p. m.	121.4	33.3	27.4	37.3	30.7	19.0	23.3	.81
	5 p. m. 7 p. m.	179.3	52.8	29.4	44.8	25.0	22.8	36.9	.62
	7 p. m. 9 p. m.	116.5	43.1	37.0	46.9	40.3	23.9	30.2	.79
	9 p. m. 11 p. m.	157.7	45.9	29.1	39.6	25.1	20.2	32.1	.63
	11 p. m. 1 a. m.	153.5	40.8	26.6	41.6	27.1	21.2	28.5	.74
	1 a. m. 3 a. m.	132.8	32.1	24.2	33.9	25.5	17.2	22.5	.77
	3 a. m. 5 a. m.	121.1	38.8	32.1	36.3	29.9	18.4	27.2	.68
	5 a. m. 7 a. m.	146.6	45.7	31.2	45.0	30.7	22.9	32.0	.72
	Total...........	1780.6	527.1	29.6	524.3	29.5	266.9	368.9	0.72

[1] See p. 122.

TABLE 174.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Experiment number, subject, and date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient. (f÷g).
82. H.C.K. 1905.	Preliminary:	*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
Nov.23–24.	7 p. m. to 9 p. m.	[1] 206.6	55.3	26.8	69.9	33.8	35.6	38.7	0.92
	9 p. m. 11 p. m.	[1] 207.6	50.8	24.5	62.1	29.9	31.6	35.5	.70
	11 p. m. 1 a. m.	[1] 169.6	47.0	27.7	60.2	35.5	30.7	32.9	.93
	1 a. m 3 a. m.	[1] 121.5	33.9	27.9	46.5	38.2	23.7	23.7	.99
	3 a. m. 5 a. m.	[1] 138.3	46.7	33.8	51.5	37.2	26.2	32.7	.80
	5 a. m. 7 a. m.	[1] 156.4	....	....	52.0	33.2	26.4	....	...
	Total, 12 hours...	[1] 1000.0	....	....	342.2	34.2	174.2	....	...
Nov.24–25.	7 a. m. to 9 a. m.	250.2	80.2	32.1	82.7	33.1	42.1	56.2	0.75
	9 a. m. 11 a. m.	241.4	65.9	27.3	72.1	29.9	36.7	46.2	.80
	11 a. m. 1 p. m.	150.5	54.3	36.1	65.8	43.7	33.5	38.0	.88
	1 p. m. 3 p. m.	215.8	63.6	29.5	71.3	33.0	36.3	44.5	.82
	3 p. m. 5 p. m.	146.1	47.2	32.3	56.0	38.3	28.5	33.0	.86
	5 p. m. 7 p. m.	165.9	47.1	28.4	56.7	34.2	28.9	33.0	.88
	7 p. m. 9 p. m.	224.9	69.2	30.8	70.4	31.3	35.8	48.4	.74
	9 p. m. 11 p. m.	199.6	58.4	29.3	62.9	31.5	32.0	40.9	.78
	11 p. m. 1 a. m.	160.2	47.3	29.5	55.8	34.8	28.4	33.1	.86
	1 a. m. 3 a. m.	145.3	44.6	30.7	47.7	32.8	24.3	31.2	.78
	3 a. m. 5 a. m.	164.2	41.5	25.3	48.3	29.4	24.6	29.1	.85
	5 a. m. 7 a. m.	157.5	43.9	27.9	51.2	32.5	26.1	30.7	.85
	Total..........	2221.6	663.2	29.9	740.9	33.4	377.2	464.3	0.81
Nov.25–26.	7 a. m. to 9 a. m.	270.8	85.6	31.6	88.8	32.8	45.2	59.9	0.75
	9 a. m. 11 a. m.	208.3	59.4	28.5	63.0	30.3	32.1	41.6	.77
	11 a. m. 1 p. m.	230.0	70.9	30.8	72.0	31.3	36.7	49.6	.74
	1 p. m. 3 p. m.	196.8	59.3	30.1	62.8	31.9	31.9	41.5	.77
	3 p. m. 5 p. m.	188.5	51.8	27.5	64.2	34.0	32.6	36.3	.90
	5 p. m. 7 p. m.	222.1	57.1	25.7	56.7	25.5	28.9	40.0	.72
	7 p. m. 9 p. m.	256.7	75.3	29.4	71.1	27.7	36.2	52.7	.69
	9 p. m. 11 p. m.	225.3	68.9	30.6	71.3	31.6	36.3	48.2	.75
	11 p. m. 1 a. m.	152.7	50.4	33.0	55.1	36.1	28.1	35.3	.80
	1 a. m. 3 a. m.	162.9	44.8	27.5	50.5	31.0	25.7	31.4	.82
	3 a. m. 5 a. m.	174.2	52.8	30.3	52.7	30.3	26.8	37.0	.73
	5 a. m. 7 a. m.	188.9	57.4	30.4	59.1	31.3	30.1	40.2	.75
	Total..........	2477.2	733.7	29.6	767.3	31.0	390.6	513.7	0.76
83. H.R.D.	Preliminary:								
Dec. 4–5...	11 p. m. to 1 a. m.	[1] 137.0	45.8	33.4	49.3	36.1	25.1	32.1	0.78
	1 a. m. 3 a. m.	[1] 128.1	32.4	25.3	36.6	28.6	18.6	22.7	.82
	3 a. m. 5 a. m.	[1] 123.3	41.9	34.0	40.2	32.6	20.5	29.3	.70
	5 a. m. 7 a. m.	[1] 118.7	32.6	27.5	42.6	35.9	21.7	22.8	.95
	Total, 8 hours....	[1] 507.1	152.7	30.1	168.7	33.3	85.9	106.9	0.80

[1] See p. 122.

TABLE 174.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Experiment number, subject, and date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
83. H.R.D. (cont.) 1905.		Cals.	Grams.		Grams.		Liters.	Liters.	
Dec. 5–6...	7 a. m. to 9 a. m.	209.5	76.9	36.7	67.8	32.4	34.5	53.8	0.64
	9 a. m. 11 a. m.	171.7	48.1	28.0	56.1	32.7	28.6	33.7	.85
	11 a. m. 1 p. m.	184.6	58.8	31.9	58.4	31.6	29.7	41.2	.72
	1 p. m. 3 p. m.	127.7	35.5	27.8	44.8	35.1	22.8	24.8	.92
	3 p. m. 5 p. m.	146.5	51.8	35.3	51.1	34.9	26.0	36.2	.72
	5 p. m. 7 p. m.	112.6	41.4	36.8	45.0	40.0	22.9	29.0	.79
	7 p. m. 9 p. m.	222.9	61.6	27.7	54.4	24.4	27.7	43.1	.64
	9 p. m. 11 p. m.	150.2	38.4	25.6	50.5	33.6	25.7	26.9	.96
	11 p. m. 1 a. m.	163.4	49.0	30.0	48.4	29.6	24.7	34.3	.72
	1 a. m. 3 a. m.	134.1	36.1	26.9	41.3	30.8	21.0	25.2	.83
	3 a. m. 5 a. m.	136.9	45.5	33.2	42.9	31.4	21.9	31.9	.69
	5 a. m. 7 a. m.	153.5	42.1	27.5	46.0	30.0	23.4	29.5	.79
	Total...........	1913.6	585.2	30.6	606.7	31.7	308.9	409.6	0.75
Dec. 6–7...	7 a. m. to 9 a. m.	220.7	74.2	33.6	67.6	30.7	34.4	51.9	0.66
	9 a. m. 11 a. m.	129.9	32.8	25.3	46.4	35.7	23.6	23.0	1.03
	11 a. m. 1 p. m.	235.3	59.3	25.2	55.3	23.5	28.2	41.6	.68
	1 p. m. 3 p. m.	113.5	32.0	28.2	44.6	39.3	22.7	22.4	1.01
	3 p. m. 5 p. m.	168.4	55.6	33.0	51.6	30.7	26.3	38.9	.68
	5 p. m. 7 p. m.	128.5	38.9	30.3	42.2	32.9	21.5	27.2	.79
	7 p. m. 9 p. m.	202.4	65.5	32.3	56.3	27.8	28.7	45.8	.63
	9 p. m. 11 p. m.	112.5	29.8	26.5	45.2	40.2	23.0	20.9	1.10
	11 p. m. 1 a. m.	163.9	36.1	22.1	42.6	26.0	21.7	25.3	.86
	1 a. m. 3 a. m.	141.2	43.9	31.1	38.9	27.5	19.8	30.7	.65
	3 a. m. 5 a. m.	127.7	39.0	30.5	41.5	32.5	21.1	27.3	.77
	5 a. m. 7 a. m.	162.8	47.3	29.0	47.0	28.9	23.9	33.1	.72
	Total...........	1906.8	554.4	29.1	579.2	30.4	294.9	388.1	0.76
85. N.M.P.	Preliminary:								
Dec. 8–9...	11 p. m. to 1 a. m.	[1] 171.3	53.0	30.9	58.3	34.0	29.7	37.1	0.80
	1 a. m. 3 a. m.	[1] 165.1	41.7	25.3	50.2	30.4	25.6	29.2	.88
	3 a. m. 5 a. m.	[1] 141.9	33.1	23.3	47.2	33.3	24.0	23.2	1.04
	5 a. m. 7 a. m.	[1] 126.9	47.7	37.6	51.9	40.9	26.4	33.4	.79
	Total, 8 hours....	[1] 605.2	175.5	29.0	207.6	34.3	105.7	122.9	0.86
Dec. 9–10..	7 a. m. to 9 a. m.	217.7	69.7	32.0	78.1	35.9	39.8	48.8	0.82
	9 a. m. 11 a. m.	196.5	55.8	28.4	62.4	31.7	31.8	39.1	.81
	11 a. m. 1 p. m.	180.2	57.0	31.6	70.1	38.9	35.7	39.9	.90
	1 p. m. 3 p. m.	152.8	47.8	31.3	55.5	36.3	28.2	33.4	.85
	3 p. m. 5 p. m.	192.6	52.1	27.1	55.4	28.8	28.2	36.5	.77
	5 p. m. 7 p. m.	160.0	49.4	30.9	57.2	35.7	29.1	34.6	.84
	7 p. m. 9 p. m.	226.7	67.1	29.6	65.4	28.9	33.3	47.0	.71
	9 p. m. 11 p. m.	162.0	51.1	31.5	54.7	33.8	27.9	35.8	.78
	11 p. m. 1 a. m.	145.7	39.9	27.4	52.0	35.7	26.5	27.9	.95
	1 a. m. 3 a. m.	157.5	46.2	29.3	46.9	29.8	23.8	32.3	.74
	3 a. m. 5 a. m.	157.8	46.0	29.2	49.9	31.6	25.4	32.2	.79
	5 a. m. 7 a. m.	159.3	45.4	28.5	49.0	30.8	24.9	31.8	.79
	Total...........	2108.8	627.5	29.8	696.6	33.0	354.6	439.3	0.81

[1] See p. 122.

TABLE 174.—*Oxygen and carbon dioxide thermal quotients and respiratory quotients*—Continued.

Experiment number, subject, and date.	Period.	(a) Total heat production.	(b) Oxygen consumed.	(c) Oxygen thermal quotient (100b÷a).	(d) Carbon dioxide eliminated.	(e) Carbon dioxide thermal quotient (100d÷a).	(f) Volume of carbon dioxide eliminated (d×0.5091).	(g) Volume of oxygen consumed (b×0.7).	(h) Respiratory quotient (f÷g).
85. N.M.P. cont.		*Cals.*	*Grams.*		*Grams.*		*Liters.*	*Liters.*	
1905. Dec. 10-11.	7 a. m. to 9 a. m.	231.0	67.3	29.2	77.0	33.3	39.2	47.1	0.83
	9 a. m. 11 a. m.	200.2	50.8	25.4	62.2	31.0	31.7	35.6	.89
	11 a. m. 1 p. m.	207.2	61.9	29.9	61.8	29.9	31.5	43.3	.73
	1 p. m. 3 p. m.	198.8	61.9	31.1	61.9	31.1	31.5	43.3	.73
	3 p. m. 5 p. m.	166.5	50.2	30.1	56.6	34.0	28.8	35.1	.82
	5 p. m. 7 p. m.	194.6	56.9	29.2	55.7	28.6	28.4	39.8	.71
	7 p. m. 9 p. m.	230.9	67.1	29.1	67.5	29.2	34.3	47.0	.73
	9 p. m. 11 p. m.	184.2	59.3	32.2	61.5	33.4	31.3	41.5	.75
	11 p. m. 1 a. m.	177.5	51.2	28.8	56.2	31.7	28.6	35.8	.80
	1 a. m. 3 a. m.	173.1	48.7	28.2	50.7	29.3	25.8	34.1	.76
	3 a. m. 5 a. m.	162.8	50.5	31.0	52.9	32.5	26.9	35.4	.76
	5 a. m. 7 a. m.	177.9	49.8	28.0	55.3	31.1	28.2	34.9	.81
	Total...........	2304.7	675.6	29.3	719.3	31.2	366.2	472.9	0.77
89. D. W.	Preliminary:								
1906. Jan. 9-10..	11 p. m. to 1 a. m.	[1] 158.1	54.8	34.7	66.2	41.9	33.7	38.3	0.88
	1 a. m. 3 a. m.	[1] 177.0	45.9	25.9	51.6	29.1	26.2	32.2	.82
	3 a. m. 5 a. m.	[1] 157.1	45.0	28.6	55.2	35.1	28.1	31.5	.89
	5 a. m. 7 a. m.	[1] 151.4	50.9	33.6	52.6	34.8	26.8	35.6	.75
	Total, 8 hours....	[1] 643.6	196.6	30.5	225.6	35.1	114.8	137.6	0.84
Jan. 10-11.	7 a. m. to 9 a. m.	231.2	62.4	27.0	75.1	32.5	38.2	43.7	0.88
	9 a. m. 11 a. m.	110.1	37.4	34.0	57.3	52.0	29.2	26.2	1.11
	11 a. m. 1 p. m.	139.2	46.8	33.6	53.3	38.3	27.1	32.8	.83
	1 p. m. 3 p. m.	256.0	67.1	26.2	65.6	25.6	33.4	47.0	.71
	3 p. m. 5 p. m.	108.6	40.0	36.8	54.4	50.1	27.7	28.0	.99
	5 p. m. 7 p. m.	241.6	68.4	28.3	63.5	26.3	32.3	47.9	.68
	7 p. m. 9 p. m.	182.2	56.3	30.9	69.4	38.1	35.3	39.4	.90
	9 p. m. 11 p. m.	236.9	79.5	33.5	74.6	31.5	38.0	55.6	.68
	11 p. m. 1 a. m.	152.2	38.9	25.6	50.3	33.0	25.6	27.2	.94
	1 a. m. 3 a. m.	154.0	46.0	29.9	48.2	31.3	24.6	32.2	.76
	3 a. m. 5 a. m.	175.1	47.7	27.2	56.7	32.4	28.9	33.4	.87
	5 a. m. 7 a. m.	163.0	54.9	33.7	54.0	33.1	27.5	38.4	.72
	Total.	2150.1	645.4	30.0	722.4	33.6	367.8	451.8	0.81
Jan. 11-12.	7 a. m. to 9 a. m.	245.1	67.2	27.4	65.7	26.8	33.4	47.1	0.71
	9 a. m. 11 a. m.	119.1	44.4	37.3	54.5	45.7	27.7	31.1	.89
	11 a. m. 1 p. m.	166.2	52.6	31.6	58.6	35.3	29.8	36.8	.81
	1 p. m. 3 p. m.	264.4	74.7	28.2	66.0	25.0	33.6	52.3	.64
	3 p. m. 5 p. m.	111.3	49.7	44.6	50.8	45.7	25.9	34.8	.74
	5 p. m. 7 p. m.	254.7	74.6	29.3	66.9	26.3	34.1	52.2	.65
	7 p. m. 9 p. m.	200.4	65.7	32.8	75.1	37.5	38.2	46.0	.83
	9 p. m. 11 p. m.	234.5	76.1	32.5	67.7	28.9	34.5	53.3	.65
	11 p. m. 1 a. m.	191.3	40.4	21.1	53.0	27.7	27.0	28.2	.96
	1 a. m. 3 a. m.	133.6	49.8	37.3	49.5	37.1	25.2	34.9	.72
	3 a. m. 5 a. m.	168.2	48.2	28.7	50.3	29.9	25.6	33.7	.76
	5 a. m. 7 a. m.	165.5	37.9	22.9	47.4	28.7	24.2	26.5	.91
	Total...........	2254.3	681.3	30.2	705.5	31.3	359.2	476.9	0.75

[1] See p. 122.

NITROGEN METABOLISM EXPERIMENTS.

Second only in importance to the study of the effect of inanition on metabolism is the study of the recovery of material lost during fasting. In the original plan under which the fasting experiments were projected a study of the recovery after fasting was contemplated. It was soon seen that such experiments were impracticable because as a rule, the subjects were unable to consume large amounts of food on the day immediately following a fast. It became necessary to modify materially the original plan and continue the food experiments in the respiration chamber for only a few days and with a small ration (hardly more than maintenance). None of the food experiments reported above were therefore of more than 3 days' duration. But although it was impossible to continue the experiments in the respiration calorimeter and thus obtain the complete balance of income and outgo, the plan was adopted of weighing and sampling all the food of the subject and noting the amounts of nitrogen, phosphorus, and sulphur in the food, feces, and urine of each day. This was done in the hope of obtaining much new information on the recoupment after prolonged inanition, since the recorded observations on the effect on metabolism of the ingestion of food after a period of inanition are extremely few.

Arrangements were made therefore to weigh and analyze all the food eaten by the subject S. A. B. from March 14, the first day after metabolism experiment No. 76, until the beginning of metabolism experiment No. 77 and from the first day after experiment No. 77, i. e., April 12, until April 25, when he left Middletown, and hence was beyond our control.

During these periods all the food and the urine and feces were sampled and analyzed. The data thus obtained constitute a study of the complete intake aud output of nitrogenous material for a period of 53 days, i. e., from the first day of fasting experiment No. 75 until April 25. The intake and output of phosphorus were likewise studied and hence the gains or losses of this element can be determined. In a measure the same is true of the sulphur balance. Furthermore, since the heat of combustion of the food eaten was determined each day, much valuable information regarding the energy consumption was secured.

Diet.—With the exception of experiment No. 77, each fast made by the subject S. A. B. was followed by an experiment in the respiration chamber in which food was given (experiments Nos. 72, 74, and 76). The change from fasting to food metabolism, therefore, was studied while the subject was in the chamber. Usually the quantities of food that the subject wished to take on the first day after the fasting period were small, barely more than enough for maintenance.

At the conclusion of the food experiment inside the chamber, which usually lasted 3 days, the subject came out of the respiration apparatus, and resumed his customary dietetic habits. After metabolism experiment No. 76, the subject began the experiment outside the chamber, the results of which are here recorded under the convenient heading of Nitrogen Metabolism Experiment No. 1. The second nitrogen metabolism experiment immediately followed metabolism experiment No. 77.

The peculiar dietetic habits of the subject of these experiments resulted in his selecting a very extended list of food materials. He was left perfectly free to choose whatever he wished both as to kinds and amounts of food. In general, meat was partaken of very sparingly. Milk, fruit, cereals, and eggs, together with peanut butter, were the chief articles of diet.

The wide variety of food selected may be seen from table 175, which gives the percentage composition and the different kinds of food used in both nitrogen metabolism experiments. The values here recorded are used in subsequent computations to test the accuracy of the method of sampling the food employed in these experiments.

The percentage composition of the foods given in this table is taken for the most part from the compilation of analyses of American food materials published by Atwater and Bryant.[a] In many instances the analyses taken from the bulletin referred to, were revised by averaging with new unpublished data.

SAMPLING AND ANALYSIS.

It was impracticable to sample and analyze each kind of food consumed each day. The following plan was therefore adopted: The amount of each kind of food eaten in a given 24 hours was determined, and a tenth of each kind of food was placed in a dish. These different samples formed, then, a composite representing one-tenth of all the food eaten and including each kind of food. This composite sample was dried in the water oven, then weighed, mixed and ground preparatory to its analysis. Determinations were made on the sample for each day, of nitrogen, phosphorus, sulphur, and the heat of combustion.

Calculated amounts of protein and energy of food.—The method of sampling and analysis outlined above is open to the objection that one or more articles of so varied a diet might be overlooked in preparing the daily composite samples. As a partial check on the accuracy of this method of sampling, the amounts of protein and energy in the food consumed per day have been computed from the weights of the different foods eaten and the percentage composition given in table 175. This table is furthermore of interest in showing the kinds and amounts of food eaten each day.

[a] U. S. Dept. Agr., Office of Expt. Sta. Bul. 28 (1898).

TABLE 175.—*Proportion of nutrients assumed*[1] *for and calculated heat of combustion of food eaten—Nitrogen metabolism experiments Nos. 1 and 2.*

Kind of food.	(a) Protein (N×6.25).	(b) Fat.	(c) Carbohydrates.	(d) Heat of combustion per gram.
	Per cent.	*Per cent.*	*Per cent.*	*Calories.*
Beefsteak	23.5	20.4	....	3.266
Chicken, canned[3]	28.6	11.6	....	2.718
Ham, pressed and deviled	19.0	34.1	....	4.313
Lamb chops[2]	21.7	....	....	4.070
Salmon, canned	21.8	12.1	....	2.381
Eggs, raw	14.8	10.5	....	1.849
Eggs, boiled	14.0	12.0	....	1.945
Butter	1.0	85.0	....	7.919
Cheese, cream	18.7	27.4	1.5	3.650
Cream	2.5	18.5	4.5	2.028
Milk	3.3	4.0	5.0	.751
Oats, rolled[4]	16.1	7.4	66.5	4.415
Wheat breakfast food[4]	14.2	3.1	73.3	4.191
Wheat breakfast food, rolled[4]	10.9	2.0	75.4	3.985
Wheat breakfast food, shredded[4]	10.6	1.4	78.1	4.025
Breakfast food, crisped and malted[4]	9.9	....	....	3.822
Bread, white	9.2	1.3	53.1	2.885
Bread, whole wheat	9.7	.9	49.7	2.734
Crackers, soda	9.8	9.1	73.1	4.485
Cake, raisin[5]	5.9	10.9	64.1	4.007
Beans, baked, canned	6.9	2.5	19.6	1.407
Carrots	1.1	.4	9.3	.483
Celery	1.1	.1	3.3	.208
Lettuce	1.2	.3	2.9	.210
Onions	1.6	.3	9.9	.524
Peas, canned	3.6	.2	9.8	.635
Tomatoes	.9	.4	3.9	.246
Olives	1.1	27.6	11.6	3.088
Apples	.3	.3	10.8	.476
Bananas	1.3	.6	22.0	1.003
Lemons	1.0	.7	8.5	.457
Oranges	.8	.2	11.6	.524
Dates, dried	2.1	2.8	78.4	3.506
Figs, dried	4.3	.3	74.2	3.219
Prunes, dried	2.1	....	73.3	3.041
Prunes, dried, soaked in water[6]	1.5	....	52.3	2.170
Raisins	2.3	3.0	68.5	3.139
Raisins, soaked in water[6]	.8	....	39.6	1.626
Almonds	21.0	54.9	17.3	7.010
Cocoanut	5.7	50.6	27.9	6.186
Cocoanut milk	.4	1.5	4.6	.353
Peanut butter	29.3	46.5	17.1	6.690
Pecans	11.0	71.2	13.3	7.795
Walnuts, English	16.6	63.4	16.1	7.502
Sugar	....	....	100.0	3.960
Honey	.4	....	81.2	3.207
Milk chocolate[7]	12.9	48.7	30.3	6.515
Molasses candy[8]	2.4	....	69.3	2.873
Cocoa (beverage)[3]	1.1	....	....	.310
Olive oil	....	100.0	....	9.300

[1] U. S. Dept. Agr., O. E. S., Bul. 28, except as noted.
[2] Composition assumed from unpublished data.
[3] Protein and energy determined. U. S. Dept. Agr., O. E. S., Bul. 152.
[4] Conn. (Storrs) Report, 1904.
[5] Composition assumed as fruit cake.
[6] Composition calculated from U. S. Dept. Agr., O. E. S., Bul. 150, by means of known percentage of water added.
[7] Assumed as chocolate.
[8] Assumed as molasses.

TABLE 176.—*Calculated protein and energy in fresh food—Nitrogen metabolism experiments Nos. 1 and 2.*

NITROGEN METABOLISM EXPERIMENT No. 1.

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 14	Eggs, boiled	101.6	14.22	198
	Butter	38.1	.38	302
	Cheese, cream	16.5	3.09	60
	Cream	235.9	5.90	478
	Milk	1057.0	34.88	794
	Wheat, rolled, raw	118.8	12.95	473
	Bread, white	69.6	6.40	201
	Bread, wheat, whole	264.4	25.65	723
	Onions, raw	75.3	1.20	39
	Apples	612.1	1.84	275
	Bananas	302.4	3.93	303
	Oranges	145.7	1.17	76
	Dates	95.7	2.01	336
	Figs	95.4	4.10	307
	Raisins	56.5	1.30	177
	Peanut butter	35.2	10.31	235
	Sugar	6.2	......	25
	Cocoa, as beverage	199.2	2.19	62
	Total for day	3525.6	131.52	5064
Mar. 15	Eggs, raw	79.4	11.75	147
	Butter	39.9	.40	316
	Cheese, cream	102.5	19.17	374
	Cream	368.8	9.23	748
	Milk	1186.4	39.15	891
	Wheat, rolled, raw	95.1	10.37	379
	Bread, white	222.9	20.51	743
	Bread, whole wheat	190.7	18.50	521
	Onions, raw	75.7	1.21	40
	Apples	352.8	1.06	168
	Bananas	435.8	5.67	437
	Oranges	624.9	5.00	327
	Dates	109.5	2.30	384
	Prunes	181.1	3.80	551
	Raisins	55.1	1.27	173
	Peanut butter	61.7	18.08	413
	Total for day	4182.3	167.47	6612
Mar. 16	Eggs, boiled and scrambled	71.1	9.95	138
	Butter	27.6	.28	218
	Cream	84.1	2.10	171
	Milk	1537.0	35.61	1155
	Bread, white	375.1	34.51	1082
	Apples	373.8	1.12	179
	Bananas	177.7	2.31	179
	Oranges	636.9	5.09	334
	Figs	71.9	3.09	231
	Peanut butter	95.4	27.96	638
	Total for day	3450.6	122.02	4325

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 17	Eggs, boiled and scrambled	81.5	11.41	159
	Butter	38.8	.38	307
	Cheese, cream	46.3	8.66	169
	Milk	748.5	24.70	562
	Bread, white	178.0	16.38	514
	Bread, whole wheat	111.3	10.80	304
	Apples	301.8	.91	144
	Bananas	189.9	2.47	190
	Oranges	310.6	2.48	163
	Figs	177.1	7.62	570
	Prunes, soaked in water	220.5	3.31	478
	Raisins, soaked in water	106.7	.85	173
	Peanut butter	27.0	7.91	181
	Total for day	2538.0	97.88	3914
Mar. 18	Eggs, raw	84.3	12.48	156
	Butter	11.0	.11	87
	Cheese, cream	35.3	6.60	131
	Cream	359.3	8.99	729
	Milk	1593.7	52.60	1197
	Wheat, rolled, raw	63.9	6.97	255
	Bread, whole wheat	316.1	30.66	864
	Apples	241.5	.72	115
	Bananas	440.1	5.72	441
	Oranges	342.5	2.74	179
	Dates	246.0	5.16	863
	Figs	86.0	3.70	277
	Prune juice	94.3	....	....
	Prunes, soaked in water	208.8	3.13	453
	Almonds	17.8	3.74	125
	Peanut butter	88.4	25.90	591
	Walnuts, English	22.4	3.72	168
	Total for day	4251.4	172.94	6631
Mar. 19	Eggs, boiled and scrambled	121.3	16.98	236
	Butter	20.7	.21	164
	Cheese, cream	46.5	8.70	170
	Cream	279.6	6.99	567
	Milk	1338.0	44.16	1005
	Wheat, rolled, raw	70.5	7.68	281
	Bread, whole wheat	106.9	10.37	292
	Crackers	48.2	4.72	216
	Onions	34.4	.55	18
	Apples	354.5	1.06	169
	Bananas	308.8	4.01	310
	Oranges	310.2	2.48	163
	Dates	141.2	2.97	495
	Raisins	52.8	1.21	166
	Honey	52.8	.21	169
	Total for day	3286.4	112.30	4421

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 20	Eggs, boiled and scrambled	90.6	12.68	176
	Butter	23.5	.24	226
	Cheese, cream	74.6	13.95	272
	Cream	310.0	7.76	628
	Milk	1361.1	44.92	1022
	Wheat, rolled, raw	82.6	9.00	329
	Bread, whole wheat	148.7	14.42	407
	Cake, raisin	44.1	2.60	177
	Bananas	449.7	5.85	552
	Oranges	148.1	1.18	78
	Dates	123.3	2.59	432
	Figs	140.0	6.02	451
	Raisins	72.9	1.68	229
	Almonds	64.0	13.44	448
	Honey	56.1	.22	180
	Walnuts, English	52.2	8.67	392
	Total for day	3241.5	145.22	5999
Mar. 21	Eggs, boiled and scrambled	69.3	9.70	135
	Butter	37.5	.38	307
	Milk	1240.7	40.94	932
	Bread, whole wheat	316.3	30.69	865
	Cake, raisin	64.5	3.81	258
	Beans, baked, canned	310.2	21.40	435
	Onions	45.8	.73	24
	Apples	330.4	.99	157
	Bananas	457.4	5.94	459
	Oranges	642.6	5.14	337
	Figs	134.3	5.77	432
	Raisins	65.8	1.51	207
	Peanut butter	57.7	16.91	386
	Total for day	3772.5	143.91	4934
Mar. 22	Eggs, boiled and scrambled	102.8	14.39	200
	Butter	86.6	.87	686
	Cream	324.5	8.11	659
	Milk	731.7	24.14	549
	Oats, rolled, raw	70.2	11.30	310
	Bread, whole wheat	337.3	32.72	922
	Crackers, soda	18.3	1.79	82
	Onions	11.2	.18	6
	Peas, canned	361.6	13.02	230
	Apples	283.1	.85	136
	Bananas	506.1	6.58	507
	Oranges	303.5	2.43	159
	Dates	198.1	4.16	695
	Figs	110.2	4.74	355
	Raisins	45.3	1.04	142
	Walnuts, English	43.2	7.17	324
	Total for day	3533.7	133.49	5962

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 23..........	Ham, pressed and deviled ..	64.4	12.24	278
	Butter......................	60.0	.60	475
	Cream......................	205.9	5.15	418
	Milk........................	484.3	15.98	364
	Wheat, rolled, raw..........	82.6	9.00	329
	Bread, whole wheat.........	177.8	17.25	486
	Apples......................	282.9	.85	135
	Bananas....................	570.9	7.42	573
	Oranges....................	323.5	2.59	170
	Dates.......................	114.5	2.40	410
	Prunes.....................	334.3	7.02	1017
	Raisins.....................	91.7	2.11	288
	Almonds....................	30.3	6.36	212
	Total for day..........	2823.1	88.97	5155
Mar. 24..........	Beefsteak...................	153.6	36.10	502
	Butter......................	56.7	.57	449
	Cream......................	205.7	5.14	417
	Milk........................	1263.3	41.69	948
	Wheat, rolled, raw..........	71.2	7.76	282
	Bread, whole wheat.........	197.4	19.15	540
	Onions.....................	45.6	.73	24
	Bananas....................	166.5	2.16	167
	Oranges....................	433.0	3.46	227
	Dates.......................	158.9	3.34	557
	Figs........................	31.5	1.35	101
	Raisins.....................	72.0	1.66	226
	Molasses candy.............	37.9	.91	109
	Total for day..........	2893.3	124.02	4549
Mar. 25..........	Eggs, boiled and scrambled..	119.4	16.72	232
	Butter......................	51.5	.52	408
	Cheese, cream..............	48.8	9.13	179
	Cream......................	248.0	6.20	503
	Milk........................	1125.2	37.14	846
	Wheat, rolled, raw..........	48.3	5.26	192
	Bread, whole wheat.........	174.1	16.89	476
	Tomatoes...................	88.4	.80	22
	Apples......................	343.8	1.03	164
	Bananas....................	402.5	5.23	404
	Oranges....................	340.0	2.72	178
	Dates.......................	119.4	2.51	419
	Figs........................	210.2	9.04	677
	Raisins.....................	53.6	1.23	168
	Pecans......................	58.5	6.44	456
	Walnuts, English...........	51.7	8.58	388
	Honey......................	102.6	.41	329
	Total for day..........	3586.0	129.85	6041

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 26	Salmon	272.1	59.32	648
	Butter	24.7	.25	196
	Cream	234.1	5.85	475
	Milk	1058.0	34.92	795
	Wheat, rolled, raw	50.2	5.47	200
	Bread, whole wheat	126.5	12.27	346
	Carrots	39.5	.43	19
	Onions	59.4	.95	31
	Peas, canned	204.0	7.34	133
	Tomatoes	100.8	.91	25
	Bananas	229.0	2.98	230
	Lemons	35.7	.36	16
	Dates	118.8	2.49	417
	Figs	73.9	3.18	238
	Raisins	65.6	1.51	206
	Cocoanut	74.4	4.24	460
	Cocoanut milk	62.6	.25	22
	Peanut butter	14.7	4.31	98
	Olive oil	15.0	......	140
	Total for day	2859.0	147.03	4695
Mar. 27	Beefsteak	35.4	8.32	116
	Lamb chops	46.6	10.11	190
	Eggs, boiled and scrambled	108.9	15.25	212
	Butter	88.8	.90	703
	Cheese, cream	61.6	11.52	225
	Cream	146.4	3.66	297
	Milk	1117.0	36.86	840
	Bread, whole wheat	409.1	39.68	1119
	Lettuce	81.0	.97	17
	Tomatoes	125.8	1.13	31
	Bananas	421.1	5.47	422
	Oranges	753.0	6.03	395
	Figs	48.4	2.08	156
	Almonds	36.0	7.56	252
	Peanut butter	44.0	12.89	294
	Pecans	47.0	5.17	366
	Walnuts, English	46.2	7.67	347
	Chocolate, milk	12.0	1.55	78
	Total for day	3628.3	176.82	6060
Mar. 28	Eggs, scrambled	160.5	22.47	312
	Butter	41.4	.41	328
	Milk	1447.7	47.77	1087
	Bread, whole wheat	219.6	21.31	600
	Peas, canned	189.2	6.81	120
	Bananas	225.9	2.94	227
	Oranges	188.0	1.50	99
	Dates	39.3	.83	138
	Prunes	298.9	6.28	909
	Raisins	65.8	1.51	207
	Honey	47.8	.19	153
	Total for day	2924.1	112.02	4180

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Mar. 29	Eggs, boiled and scrambled	126.1	17.65	245
	Butter	34.8	.35	276
	Cream	83.0	2.08	168
	Milk	836.9	27.62	628
	Bread, whole wheat	128.4	12.45	351
	Carrots	35.4	.39	17
	Lettuce	54.3	.65	11
	Onions	49.4	.79	26
	Tomatoes	96.7	.87	24
	Apples	211.8	.64	101
	Bananas	264.1	3.43	265
	Lemons	21.8	.22	10
	Oranges	179.2	1.43	94
	Dates	120.2	2.52	421
	Raisins	53.1	1.22	167
	Almonds	53.7	11.28	376
	Pecans	45.2	4.97	352
	Walnuts, English	42.3	7.02	317
	Olive oil	12.8	.....	119
	Total for day	2449.2	95.58	3968
Mar. 30	Butter	45.1	.45	357
	Cream	175.9	4.40	357
	Milk	506.8	16.72	380
	Wheat, rolled, raw	37.3	4.07	149
	Bread, whole wheat	139.6	13.54	382
	Beans, baked, canned	392.5	27.08	550
	Lettuce	98.4	1.18	21
	Onions	97.4	1.56	51
	Tomatoes	139.3	1.25	34
	Apples	232.0	.70	110
	Bananas	180.4	2.35	181
	Lemons	21.5	.22	10
	Oranges	129.1	1.03	68
	Dates	78.5	1.65	275
	Raisins	87.0	2.00	273
	Honey	46.3	.19	148
	Total for day	2407.1	78.39	3346
Mar. 31	Salmon, canned	250.3	54.57	596
	Butter	36.6	.37	290
	Cream	191.8	4.80	389
	Milk	1456.2	48.06	1094
	Wheat breakfast food, raw	26.4	3.75	111
	Wheat, rolled, raw	42.2	4.60	168
	Bread, whole wheat	144.5	14.02	395
	Tomatoes	179.8	1.62	44
	Apples	213.6	.64	102
	Bananas	193.9	2.52	194
	Oranges	117.2	.94	61
	Dates	54.8	1.15	192
	Raisins	69.2	1.59	217
	Pecans	30.1	3.31	235
	Walnuts, English	32.8	5.44	246
	Total for day	3039.4	147.38	4334

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Apr. 1	Salmon, canned	61.0	13.30	145
	Eggs, boiled and scrambled	88.6	12.40	172
	Butter	65.2	.65	516
	Cheese, cream	55.2	10.32	201
	Cream	168.4	4.21	342
	Milk	1610.7	53.15	1210
	Bread, whole wheat	211.7	20.54	579
	Peas, canned	209.7	7.55	133
	Tomatoes	133.3	1.20	33
	Bananas	147.5	1.92	148
	Oranges	293.2	2.35	154
	Prunes	148.8	3.12	453
	Peanut butter	23.5	6.89	157
	Total for day	3216.8	137.60	4243
Apr. 2	Beefsteak	166.9	39.22	545
	Butter	33.5	.34	265
	Cream	152.6	3.82	309
	Milk	1259.1	41.55	946
	Wheat, rolled, raw	48.4	5.28	193
	Bread, whole wheat	108.8	10.55	297
	Lettuce	142.5	1.71	30
	Onions	81.3	1.30	43
	Tomatoes	222.8	2.01	55
	Apples	355.8	1.07	169
	Bananas	209.1	2.72	210
	Oranges	259.7	2.08	136
	Dates	63.5	1.33	223
	Figs	39.3	1.69	127
	Raisins	40.9	.94	128
	Total for day	3184.2	115.61	3676
Apr. 3	Eggs, boiled	82.3	11.52	160
	Butter	29.6	.30	234
	Cheese, cream	66.6	12.45	243
	Cream	321.9	8.05	753
	Milk	861.0	28.42	646
	Wheat breakfast food, shredded	58.2	6.17	234
	Bread, whole wheat	104.5	10.14	286
	Apples	231.2	.69	110
	Bananas	375.9	4.89	377
	Oranges	260.1	2.08	136
	Raisins	18.8	.43	59
	Walnuts, English	56.4	9.36	423
	Total for day	2466.5	94.50	3661

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1906.		*Grams.*	*Grams.*	*Calories.*
Apr. 4	Eggs	136.3	19.08	265
	Butter	30.3	.30	240
	Cream	296.5	7.41	601
	Milk	868.4	28.66	653
	Wheat, rolled, raw	34.5	3.76	137
	Bread, whole wheat	108.1	10.49	276
	Tomatoes	219.7	1.98	54
	Apples	203.8	0.61	97
	Bananas	198.0	2.57	199
	Raisins	71.0	1.63	223
	Peanut butter	46.4	13.60	310
	Total for day	2213.0	90.09	3055
Apr. 5	Beefsteak	165.8	38.96	542
	Butter	35.1	.35	278
	Cream	337.8	8.44	685
	Milk	859.8	28.38	646
	Wheat, rolled	36.2	3.95	144
	Bread, white	106.8	10.36	292
	Onions	75.9	1.21	40
	Tomatoes	132.3	1.19	33
	Apples	260.8	.78	124
	Bananas	357.8	4.65	359
	Dates	76.3	1.60	268
	Figs	320.8	13.79	1033
	Raisins	41.2	.95	129
	Total for day	2806.6	114.61	4573
Apr. 6	Butter	36.5	.37	289
	Cream	227.7	5.69	462
	Milk	1395.5	46.05	1048
	Wheat breakfast food, shredded	59.0	6.25	237
	Bread, white	106.7	10.35	292
	Beans, baked, canned	355.3	24.52	498
	Lettuce	115.7	1.39	24
	Apples	150.1	.45	71
	Bananas	157.3	2.04	158
	Lemons	14.1	.14	6
	Oranges	146.6	1.17	77
	Almonds	55.3	11.61	388
	Pecans	49.7	5.47	387
	Total for day	2869.5	115.50	3937

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 1 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Apr. 7	Eggs, boiled and scrambled	100.9	14.13	196
	Butter	37.0	.37	293
	Cheese	30.9	5.78	113
	Milk	783.4	25.85	589
	Bread, white	64.7	6.28	177
	Bread, whole wheat	91.9	8.91	251
	Beans, baked, canned	225.6	15.57	316
	Oranges	129.0	1.03	68
	Figs	76.9	3.31	248
	Raisins	128.2	2.95	402
	Total for day	1668.5	84.18	2653

NITROGEN METABOLISM EXPERIMENT No. 2.

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.				
Apr. 12	Milk	665.9	21.97	500
	Bread	166.6	15.33	481
	Tomatoes	124.9	1.12	31
	Lemons	158.4	1.58	72
	Oranges	433.8	3.47	227
	Total for day	1549.6	43.47	1311
Apr. 13	Beefsteak	123.7	29.07	404
	Egg, raw	26.7	3.95	49
	Butter	47.7	.48	378
	Cheese	50.5	9.44	184
	Milk	761.0	25.11	572
	Bread	269.4	24.78	777
	Lettuce	88.5	1.06	19
	Onions	46.3	.74	24
	Tomatoes	262.2	2.36	65
	Bananas	79.9	1.04	80
	Lemons	206.5	2.07	94
	Oranges	330.8	2.65	173
	Total for day	2293.2	102.75	2819
Apr. 14	Salmon, canned	164.9	35.95	393
	Egg, raw	20.3	3.00	38
	Butter	21.6	.22	171
	Cream	131.3	3.28	266
	Milk	931.0	30.72	699
	Wheat germ food	27.8	3.95	117
	Bread	146.6	13.49	423
	Peas[1]	139.5	5.02	89
	Tomatoes	178.5	1.61	44
	Bananas	136.0	1.77	136
	Lemons	17.8	.18	8
	Oranges	160.4	1.28	84
	Dates	81.7	1.72	286
	Prunes, soaked in water	236.6	3.55	513
	Raisins	24.3	.56	76
	Peanut butter	45.8	13.42	306
	Total for day	2464.1	119.72	3649

[1] Composition assumed as canned peas.

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 2 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1906.		*Grams.*	*Grams.*	*Calories.*
Apr. 15..........	Chicken, canned............	131.0	37.47	356
	Salmon....................	114.7	25.00	273
	Butter.....................	26.3	.26	208
	Milk.......................	1481.1	48.88	1112
	Bread......................	260.7	23.98	752
	Celery.....................	61.8	.68	13
	Peas[1]....................	179.3	6.45	114
	Tomatoes...................	156.1	1.40	38
	Apples.....................	142.1	.43	68
	Bananas....................	307.0	3.99	308
	Oranges....................	114.9	.92	60
	Total for day..........	2975.0	149.46	3302
Apr. 16..........	Beefsteak..................	177.1	41.62	578
	Eggs, raw..................	114.4	16.93	212
	Cream......................	146.4	3.66	297
	Cheese.....................	54.2	10.14	198
	Milk.......................	1322.5	43.64	993
	Bread, whole wheat.........	206.1	19.99	563
	Celery.....................	81.0	.89	16
	Tomatoes...................	135.0	1.22	33
	Olives.....................	39.9	.44	123
	Apples.....................	332.9	1.00	158
	Oranges....................	160.4	1.28	84
	Total for day..........	2769.9	140.81	3255
Apr. 17..........	Eggs, boiled and scrambled..	139.4	19.52	271
	Cream......................	186.0	4.65	377
	Milk.......................	1657.3	54.69	1245
	Bread......................	281.5	25.90	812
	Beans, baked, canned.......	396.4	27.35	555
	Lettuce....................	128.4	1.54	27
	Tomatoes...................	166.3	1.50	41
	Bananas....................	313.2	4.07	314
	Oranges....................	170.0	1.36	89
	Dates......................	119.4	2.51	419
	Peanut butter..............	79.2	23.21	530
	Pecans.....................	61.4	6.75	479
	Walnuts, English...........	56.7	9.41	425
	Total for day..........	3755.2	182.46	5584
Apr. 18..........	Beefsteak..................	192.2	45.17	628
	Cream......................	175.0	4.38	355
	Milk.......................	1142.9	37.72	858
	Wheat, rolled..............	25.4	2.77	101
	Bread......................	118.2	10.87	341
	Bananas....................	129.7	1.69	130
	Oranges....................	176.4	1.41	92
	Dates......................	139.9	2.94	490
	Prunes, soaked in water....	267.0	4.01	579
	Raisins....................	28.4	.65	89
	Almonds....................	68.9	14.47	483
	Total for day..........	2464.0	126.08	4146

[1] Composition assumed as canned peas.

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 2 (Cont'd).				
Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1905.		*Grams.*	*Grams.*	*Calories.*
Apr. 19	Milk	1313.1	43.33	986
	Bread	197.1	18.13	569
	Beans	388.6	26.81	544
	Celery	31.5	.35	6
	Lettuce	18.9	.23	4
	Tomatoes	243.0	2.19	60
	Bananas	193.8	2.52	194
	Oranges	190.8	1.53	100
	Dates	93.1	1.96	326
	Peanut butter	61.3	17.96	410
	Total for day	2731.2	115.01	3199
Apr. 20	Beefsteak	168.1	39.50	549
	Eggs, boiled and scrambled	147.9	20.71	288
	Cheese	69.3	12.96	253
	Milk	1291.3	42.61	970
	Bread	178.5	16.42	515
	Celery	48.0	.53	10
	Onions	51.9	.83	27
	Tomatoes	148.4	1.34	37
	Apples	279.7	.84	133
	Bananas	134.3	1.75	135
	Oranges	210.6	1.68	110
	Total for day	2728.0	139.17	3027
Apr. 21	Salmon, canned	234.9	51.21	559
	Butter	31.6	.32	250
	Cream	184.6	4.62	374
	Milk	1111.3	36.67	835
	Wheat, raw	35.3	3.85	141
	Bread	120.6	11.10	348
	Celery	51.1	.56	10
	Onions, raw	64.1	1.03	34
	Apples	370.1	1.11	176
	Bananas	252.6	3.28	253
	Oranges	129.8	1.04	68
	Dates	153.1	3.22	537
	Raisins	43.1	.99	135
	Total for day	2782.2	119.00	3720
Apr. 22	Chicken, canned	95.0	27.17	258
	Butter	22.3	.22	177
	Cream	198.4	4.96	402
	Milk	1208.3	39.87	907
	Bread	193.2	17.77	557
	Celery	76.1	.84	15
	Tomatoes	155.0	1.40	38
	Bananas	155.2	2.02	156
	Oranges	372.4	2.98	195
	Dates	46.0	.97	161
	Raisins	45.3	1.04	142
	Total for day	2567.2	99.24	3008

TABLE 176.—*Calculated protein and energy in fresh food*—Continued.

NITROGEN METABOLISM EXPERIMENT No. 2 (Cont'd).

Date.	Kind of food.	(a) Weight of food.	(b) Protein.	(c) Energy.
1906.		*Grams.*	*Grams.*	*Calories.*
Apr. 23	Beefsteak	182.4	42.86	596
	Butter	23.8	.24	188
	Cream	181.2	4.53	367
	Milk	1186.0	39.14	891
	Wheat, raw	50.7	5.53	202
	Bread	118.8	10.93	343
	Tomatoes	211.3	1.90	52
	Bananas	272.6	3.54	273
	Oranges	168.8	1.35	88
	Dates	89.6	1.88	314
	Prunes	49.9	.75	108
	Pecans	80.4	8.84	627
	Walnuts, English	61.6	10.23	462
	Total for day	2677.1	131.72	4511
Apr. 24	Salmon, canned	168.0	36.62	400
	Eggs, fried [1]	78.7	11.65	146
	Cheese	38.2	7.14	139
	Milk	1375.5	45.39	1033
	Bread	151.0	13.89	436
	Celery	51.2	.56	10
	Tomatoes	289.8	2.61	71
	Olives	46.6	.51	144
	Bananas	188.6	2.45	189
	Oranges	298.0	2.38	156
	Total for day	2685.6	123.20	2724
Apr. 25	Lamb chops	101.7	22.07	414
	Cream	186.1	4.65	377
	Milk	1497.4	49.41	1125
	Wheat breakfast food	43.5	4.31	166
	Bread	157.6	14.50	455
	Lettuce	119.7	1.44	25
	Tomatoes	324.2	2.92	80
	Bananas	200.5	2.61	201
	Oranges	232.9	1.86	122
	Dates	106.3	2.23	373
	Total for day	2969.9	106.00	3338

[1] Composition assumed to be the same as for raw.

Determinations of nitrogen, phosphorus, sulphur, and heat of combustion of food.—While for the approximations of the ordinary dietary study the use of average figures for the percentage composition of food materials is fully justified, in an accurate balance experiment in which it is desired to know the income and outgo of material and energy, accurate analyses alone can be used.

Such analyses were made of the composite sample of food for each day. The results are given in table 177, which includes also the total amounts of each element determined and the total energy of the food for each week and the average per day.

TABLE 177.—*Amounts of determined nitrogen, protein, phosphorus, sulphur, and energy in food—Nitrogen metabolism experiments Nos. 1 and 2.*

Laboratory number.	Experiment number and date.	(a) Nitrogen.	(b) Protein ($N \times 6.25$).	(c) Phosphorus.	(d) Phosphoric acid (P_2O_5).	(e) Sulphur.	(f) Sulphur trioxide (SO_3).	(g) Heat of combustion.
	Experiment No. 1.							
	First week:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3864	Mar. 14–15, 1905	20.55	128.44	4.479	10.257	1.822	4.547	5,592
3865	Mar. 15–16, 1905	25.09	156.81	6.853	15.696	2.038	5.086	6,771
3866	Mar. 16–17, 1905	21.65	135.31	5.162	11.823	1.142	2.851	4,857
3867	Mar. 17–18, 1905	14.90	93.13	4.228	9.685	.335	.836	3,943
3868	Mar. 18–19, 1905	26.34	164.62	3.895	8.922	1.613	4.025	6,527
3869	Mar. 19–20, 1905	17.10	106.88	3.420	7.833	1.135	2.834	4,810
3870	Mar. 20–21, 1905	22.14	138.38	4.703	10.770	3.066	7.652	6,200
	Total for 1st week	147.77	923.57	32.740	74.986	11.151	27.831	38,700
	Average per day	21.11	131.94	4.677	10.712	1.593	3.976	5,529
	Second week:							
3871	Mar. 21–22, 1905	22.14	138.38	3.461	7.926	1.538	3.839	5,611
3872	Mar. 22–23, 1905	19.90	124.38	4.000	9.161	1.577	3.938	6,092
3873	Mar. 23–24, 1905	15.01	93.81	2.260	5.175	1.095	2.733	4,598
3874	Mar. 24–25, 1905	21.55	134.69	3.716	8.510	1.569	3.916	4,847
3875	Mar. 25–26, 1905	20.80	130.00	4.534	10.385	1.764	4.403	6,786
3876	Mar. 26–27, 1905	25.55	159.69	4.006	9.176	1.922	4.797	4,752
3877	Mar. 27–28, 1905	27.64	172.75	4.610	10.558	2.061	5.143	6,507
	Total for 2d week	152.59	953.70	26.587	60.891	11.526	28.769	39,193
	Average per day	21.80	136.24	3.798	8.699	1.647	4.110	5,599
	Third week:							
3878	Mar. 28–29, 1905	16.62	103.88	2.755	6.311	1.444	3.606	3,874
3879	Mar. 29–30, 1905	12.83	80.19	2.053	4.701	1.094	2.730	3,440
3880	Mar. 30–31, 1905	11.74	73.38	1.922	4.401	1.036	2.586	3,446
3881	Mar. 31-April 1, 1905	24.69	154.31	3.188	7.301	1.677	4.187	4,357
3882	Apr. 1–2, 1905	22.65	141.56	3.220	7.376	1.609	4.015	4,356
3883	Apr. 2–3, 1905	19.14	119.63	2.586	5.922	1.419	3.541	3,798
3884	Apr. 3–4, 1905	13.99	87.44	2.306	5.281	.972	2.426	3,847
	Total for 3d week	121.66	760.39	18.030	41.293	9.251	23.091	27,118
	Average per day	17.38	108.63	2.576	5.899	1.322	3.299	3,874
	Fourth week:							
3885	Apr. 4–5, 1905	14.03	87.69	2.194	5.025	1.070	2.671	3,395
3886	Apr. 5–6, 1905	17.91	111.94	2.467	5.651	1.430	3.569	4,640
3887	Apr. 6–7, 1905	18.01	112.56	3.171	7.263	1.211	3.020	4,208
3888	Apr. 7–8, 1905	12.73	79.56	1.927	4.413	.990	2.471	2,752
	Total for 4 days	62.68	391.75	9.759	22.352	4.701	11.731	14,995
	Average per day	15.67	97.94	2.440	5.588	1.175	2.933	3,749
	Experiment No. 2.							
	First week:							
3893	Apr. 12–13, 1905	7.10	44.38	1.185	2.713	.610	1.522	1,334
3894	Apr. 13–14, 1905	16.23	101.44	1.958	4.484	1.275	3.183	2,806
3895	Apr. 14–15, 1905	20.04	125.25	2.575	5.897	1.452	3.624	3,573
3896	Apr. 15–16, 1905	23.81	148.81	2.759	6.320	1.727	4.312	3,300
3897	Apr. 16–17, 1905	21.67	135.44	2.635	6.035	1.525	3.805	3,362
3898	Apr. 17–18, 1905	28.98	181.13	4.302	9.854	2.037	5.084	5,621
3899	Apr. 18–19, 1905	19.45	121.56	2.586	5.923	1.264	3.155	3,768
	Total for 1st week	137.28	858.01	18.000	41.226	9.890	24.685	23,764
	Average per day	19.61	122.57	2.571	5.889	1.413	3.526	3,395

TABLE 177.—*Amounts of determined nitrogen, protein, phosphorus, sulphur, and energy in food*—Continued.

Laboratory number.	Experiment number and date.	(a) Nitrogen.	(b) Protein ($N\times 6.25$).	(c) Phosphorus.	(d) Phosphoric acid (P_2O_5).	(e) Sulphur.	(f) Sulphur trioxide (SO_3).	(g) Heat of combustion.
	Experiment No. 2—Cont'd.							
	Second week:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3900	Apr. 19–20, 1905.......	19.05	119.06	2.674	6.124	1.243	3.102	3,086
3901	Apr. 20–21, 1905.......	22.72	142.00	2.592	5.936	1.582	3.949	3,146
3902	Apr. 21–22, 1905.......	20.22	126.38	2.613	5.984	1.509	3.766	3,752
3903	Apr. 22–23, 1905.......	14.93	93.31	2.181	4.996	1.170	2.919	2,890
3904	Apr. 23–24, 1905.......	21.57	134.81	2.896	6.633	1.538	3.840	4,411
3905	Apr. 24–25, 1905.......	20.28	126.75	2.519	5.770	1.387	3.462	2,865
3906	Apr. 25–26, 1905.......	17.12	107.00	2.606	5.968	1.171	2.922	3,295
	Total for 2d week.....	135.89	849.31	18.081	41.411	9.600	23.960	23,445
	Average per day	19.41	121.33	2.583	5.916	1.372	3.423	3,349

Comparison of calculated and determined amounts of protein and energy of food.—For reasons which will appear later, it seemed desirable to obtain some check upon the analytical work connected with the determination of nitrogen, and also upon the heats of combustion determined by the bomb calorimeter. The calculated protein and energy shown in table 176 were obtained primarily for this purpose. In table 178 the comparison of the calculated with the determined results is shown. It should be stated, however, that the unusual care taken in the preparation and analysis of these samples renders the comparison a test of the accuracy of the average figures rather than a check on the analyses. The comparison is nevertheless not without interest and it is accordingly here presented.

TABLE 178.—*Comparison of determined with calculated protein and energy of food—Nitrogen metabolism experiments Nos. 1 and 2.*

Date.	Protein ($N\times 6.25$).			Energy.		
	(a) Determined.	(b) Calculated.	(c) Amount determined greater (+) or less (−) than calculated (a−b).	(d) Determined.	(e) Calculated.	(f) Amount determined greater (+) or less (−) than calculated (d−e).
Experiment No. 1.						
First week:	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
Mar 14–15, 1905......	128.44	131.52	− 3.08	5,592	5,064	+ 528
Mar. 15–16, 1905......	156.81	167.47	−10.66	6,771	6,612	+ 159
Mar. 16–17, 1905......	135.31	122.02	+13.29	4,857	4,325	+ 532
Mar. 17–18, 1905......	93.13	97.88	− 4.75	3,943	3,914	+ 29
Mar. 18–19, 1905......	164.62	172.94	− 8.32	6,527	6,631	− 104
Mar. 19–20, 1905......	106.88	112.30	− 5.42	4,810	4,421	+ 389
Mar. 20–21, 1905......	138.38	145.22	− 6.84	6,200	5,999	+ 201
Total for 1st week....	923.57	949.35	−25.78	38,700	36,966	+1734
Average per day.....	131.94	135.62	− 3.68	5,529	5,281	+ 248

TABLE 178.—*Comparison of determined with calculated protein and energy of food*—Continued.

Date.	Protein ($N \times 6.25$).			Energy.		
	(a) Determined.	(b) Calculated.	(c) Amount determined greater (+) or less (−) than calculated (a−b).	(d) Determined.	(e) Calculated.	(f) Amount determined greater (+) or less (−) than calculated (d−e).
Experiment No. 1—Cont'd.						
Second week:	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
Mar. 21–22, 1905......	138.38	143.91	− 5.53	5,611	4,934	+ 677
Mar. 22–23, 1905......	124.38	133.49	− 9.11	6,092	5,962	+ 130
Mar. 23–24, 1905......	93.81	88.97	+ 4.84	4,598	5,155	− 557
Mar. 24–25, 1905......	134.69	124.02	+10.67	4,847	4,549	+ 298
Mar. 25–26, 1905......	130.00	129.85	+ .15	6,786	6,041	+ 745
Mar. 26–27, 1905......	159.69	147.03	+12.66	4,752	4,695	+ 57
Mar. 27–28, 1905	172.75	176.82	− 4.07	6,507	6,060	+ 447
Total for 2d week....	953.70	944.09	+ 9.61	39,193	37,396	+1797
Average per day.....	136.24	134.87	+ 1.37	5,599	5,342	+ 257
Third week:						
Mar. 28–29, 1905......	103.8[illegible]	112.02	− 8.14	3,874	4,180	− 306
Mar. 29–30, 1905......	80.19	95.58	−15.39	3,440	3,968	− 528
Mar. 30–31, 1905......	73.38	78.39	− 5.01	3,446	3,346	+ 100
Mar. 31–Apr. 1, 1905...	154.31	147.38	+ 6.93	4,357	4,334	+ 23
Apr. 1–2, 1905........	141.56	137.60	+ 3.96	4,356	4,243	+ 113
Apr. 2–3, 1905........	119.63	115.61	+ 4.02	3,798	3,676	+ 122
Apr. 3–4, 1905........	87.44	94.50	− 7.06	3,847	3,661	+ 186
Total for 3d week....	760.39	781.08	−20.69	27,118	27,408	− 290
Average per day.....	108.63	111.58	− 2.96	3,874	3,915	− 41
Fourth week:						
Apr. 4–5, 1905........	87.69	90.09	− 2.40	3,395	3,055	+ 340
Apr. 5–6, 1905........	111.94	114.61	− 2.67	4,640	4,573	+ 67
Apr. 6–7, 1905........	112.56	115.50	− 2.94	4,208	3,937	+ 271
Apr. 7–8, 1905........	79.56	84.18	− 4.62	2,752	2,653	+ 99
Total for 4 days.....	391.75	404.38	−12.63	14,995	14,218	+ 777
Average per day.....	97.94	101.10	− 3.16	3,749	3,555	+ 194
Experiment No. 2.						
First week:						
Apr. 12–13, 1905......	44.38	43.47	+ .91	1,334	1,311	+ 23
Apr. 13–14, 1905......	101.44	102.75	− 1.31	2,806	2,819	− 13
Apr. 14–15, 1905......	125.25	119.72	+ 5.53	3,573	3,649	− 76
Apr. 15–16, 1905......	148.81	149.46	− .65	3,300	3,302	− 2
Apr. 16–17, 1905......	135.44	140.81	− 5.37	3,362	3,255	+ 107
Apr. 17–18, 1905......	181.13	182.46	− 1.33	5,621	5,584	+ 37
Apr. 18–19, 1905......	121.56	126.08	− 4.52	3,768	4,146	− 378
Total for 1st week....	858.01	864.75	− 6.74	23,764	24,066	− 302
Average per day.....	122.57	123.54	− .97	3,395	3,438	− 43
Second week:						
Apr. 19–20, 1905......	119.06	115.01	+ 4.05	3,086	3,199	− 113
Apr. 20–21, 1905......	142.00	139.17	+ 2.83	3,146	3,027	+ 119
Apr. 21–22, 1905......	126.38	119.00	+ 7.38	3,752	3,720	+ 32
Apr. 22–23, 1905......	93.31	99.24	− 5.93	2,890	3,008	− 118
Apr. 23–24, 1905......	134.81	131.72	+ 3.09	4,411	4,511	− 100
Apr. 24–25, 1905......	126.75	123.20	+ 3.55	2,865	2,724	+ 141
Apr. 25–26, 1905......	107.00	106.00	+ 1.00	3,295	3,338	− 43
Total for 2d week...	849.31	833.34	+15.97	23,445	23,527	− 82
Average per day.....	121.33	119.05	+ 2.28	3,349	3,361	− 12

A comparison of the computed and determined amounts of protein shows that considerable differences appear on individual days, ranging in nitrogen metabolism experiment No. 1 from +13.29 grams on March 16-17 to — 15.39 grams on March 29-30. The differences are less in the second experiment, +7.38 to —5.93 grams.

The average daily results for the different weeks show very much smaller discrepancies. The grand average for experiment No. 1 shows about 2 grams more per day by calculation than by actual determination, a difference of approximately 2 per cent.

The agreement in the two methods of obtaining the amounts of protein in the second experiment is all that could be desired. The average amounts per day show discrepancies for 2 weeks of the experiment of less than 1 per cent.

The general uniformity observed in the calculated amounts of protein when compared to the determined amounts is unfortunately not recognized so readily in the energy determinations. The variations in experiment No. 1 in the amounts of energy run from —557 calories on March 23-24 to +745 on March 25-26. On the average the energy as calculated is less than that actually determined by about 160 calories per day. It is to be borne in mind, however, that the quantities of energy are, in general, very large averaging about 4500 calories per day. Thus the average discrepancy is about 4 per cent. It is interesting to note that in the majority of instances no uniformity exists between the discrepancies appearing in the protein and the energy, though on March 29-30 the large minus discrepancy (in terms of the amount calculated) in the protein corresponds with a very large minus difference in the energy. On March 16-17 also, when large discrepancies are found in both protein and energy, both results in terms of the amount calculated are positive. In the second experiment the agreement between the calculated and determined amounts of protein and energy is very satisfactory.

On the whole the agreement between the amounts calculated and those determined is sufficiently close to indicate that there was no material error, either in sampling or in analysis.

Feces.—The time of defecation, the weights of fresh feces, and air-dry material[34] are recorded in table 179.

The copious defecations are especially noticeable. For example, on March 19 there were 349.4 grams of fresh feces passed at 9^h 15^m a. m., and at 5 p. m. of the same day 262.4 grams were excreted, i. e., 611.8 grams of feces were passed within 8 hours. Indeed, the next morning at 8.30 there was a defecation amounting to 312.4 grams. Within 24 hours, therefore, this subject excreted 924.2 grams of fresh feces.

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[34] Dried in a water oven and allowed to stand in the laboratory for 36 hours before weighing.

TABLE 179.—*Feces passed—Nitrogen metabolism experiments Nos. 1 and 2.*

Date.	Time.	(a) Weight of fresh substance.	(b) Weight of partially dried substance.
NITROGEN METABOLISM EXP'T No. 1.			
First week:			
1905.		*Grams.*	*Grams.*
Mar. 15....	8^h00^m a.m.	221.7	42.8
Mar. 16....	8 00 a.m.	108.4	23.6
	7 00 p.m.	176.6	33.5
Mar. 17....	8 00 a.m.	122.9	23.3
Mar. 18....	2 30 p.m.	43.6	9.7
Mar. 19....	9 15 a.m.	349.4	64.1
	5 00 p.m.	262.4	50.1
Mar. 20....	8 30 a.m.	312.4	48.0
	10 00 p.m.	113.5	27.1
Mar. 21....	8 30 a.m.	193.7	46.0
	7 15 p.m.	[1] 94.2	26.5
Total, 1st week.....		1998.8	394.7
Second week:			
Mar. 21 ...	7^h15^m p.m.	61.4	14.2
Mar. 22....	8 30 a.m.	291.7	66.9
	7 30 p.m.	210.6	48.1
Mar. 23....	8 30 a.m.	139.3	32.6
	2 00 p.m.	211.2	52.7
	7 10 p.m.	246.5	39.0
Mar. 24....	8 30 a.m.	126.0	30.8
	7 00 p.m.	190.1	44.9
Mar. 25....	8 30 a.m.	81.7	25.1
	6 15 p.m.	230.7	44.3
Mar. 26....	9 30 a.m.	305.6	64.2
	7 00 p.m.	195.4	46.9
Mar. 27....	8 00 a.m.	229.8	53.3
	8 30 p.m.	74.3	20.3
Mar. 28....	8 30 a.m.	262.3	52.7
	7 30 p.m.	100.6	28.4
Total, 2d week......		2957.2	664.4
Third week:			
Mar. 29....	8^h00^m a.m.	160.6	35.0
	7 00 p.m.	138.9	30.6
Mar. 30....	8 15 a.m.	182.9	44.5
	6 00 p.m.	55.1	20.0
Mar. 31....	8 30 a.m.	39.0	12.0
	2 00 p.m.	298.2	55.5
	5 30 p.m.	43.5	11.5
Apr. 1.....	8 00 a.m.	149.7	37.7
	5 30 p.m.	104.5	37.4
Apr. 2.....	8 00 a.m.	150.1	38.5
	5 00 p.m.	83.5	20.6
Apr. 3.....	8 00 a.m.	205.9	39.1
	2 30 p.m.	22.1	10.2
Apr. 4.....	8 05 a.m.	98.8	29.5
	2 45 p.m.	77.9	21.1
Total, 3d week........		1810.7	443.2

Date.	Time.	(a) Weight of fresh substance.	(b) Weight of partially dried substance.
NITROGEN METABOLISM EXP'T No. 1.			
Fourth week:[2]			
1905.		*Grams.*	*Grams.*
Apr. 5.....	9^h40^m a.m.	198.8	43.4
	5 50 p.m.	63.9	19.5
Apr. 6.....	7 55 a.m.	217.7	49.0
	6 00 p.m.	122.4	27.6
Apr. 7.....	7 30 a.m.	179.1	41.1
Apr. 8.....	7 36 a.m.	141.0	33.2
Apr. 9.....	[3]9 30 p.m.	188.3	10.2
Apr. 13....	8 15 a.m.	20.4	10.4
Total, 9 days.......		1131.6	234.4
NITROGEN METABOLISM EXP'T No. 2.			
First week:			
Apr. 14....	8^h05^m a.m.	183.9	46.5
	1 30 p.m.	139.7	23.3
Apr. 15....	8 15 a.m.	163.3	46.2
	12 35 p.m.	37.8	12.1
	6 45 p.m.	66.2	14.7
Apr. 16....	9 25 a.m.	46.8	14.3
	5 55 p.m.	45.1	14.1
Apr. 17....	7 20 a.m.	301.8	51.5
	6 15 p.m.	49.8	11.2
Apr. 18....	8 30 a.m.	60.4	14.4
	5 20 p.m.	102.5	29.3
Apr. 19....	8 10 a.m.	196.8	48.9
	5 45 p.m.	67.9	22.0
Total, 1st week.....		1462.0	348.5
Second week:			
Apr. 19....	5^h45^m p.m.	[4] 31.2	9.8
Apr. 20....	7 50 a.m.	165.0	33.7
	5 15 p.m.	96.5	25.2
Apr. 21....	6 30 a.m.	92.5	20.3
	5 25 p.m.	90.2	23.5
Apr. 22....	7 35 a.m.	159.4	32.7
	5 35 p.m.	64.3	19.2
Apr. 23....	9 30 a.m.	118.1	30.2
	5 15 p.m.	70.6	15.5
	11 30 p.m.	26.2	6.9
Apr. 24....	7 10 a.m.	256.1	53.5
	4 55 p.m.	19.6	5.9
Apr. 25....	5 30 a.m.	53.2	11.1
	10 45 a.m.	118.9	24.3
	5 25 p.m.	38.5	8.4
Apr. 26....	8 00 a.m.	162.6	37.4
Total, 2d week........		1562.9	357.6

[1] Separation between this and the following amount.
[2] See note 2, table 180.
[3] After enema.
[4] Showed lampblack from capsule taken with breakfast April 19, included with feces for week beginning April 20.

The "dried" feces were not absolutely anhydrous, but the comparison between the weights of the fresh and dried material indicates considerable variations in the percentages of water in the feces from day to day. Thus in the 246.5 grams of fresh feces passed March 23 at 7h 10m p. m. there were but 39.0 grams of air-dry material. Allowing 5 per cent of water in the air-dry material, the water-free substance would constitute only 15 per cent of the whole amount, an unusually low percentage. There was no indication that the subject had any diarrhœa.

The 20.4 grams of feces passed on April 13, at 8h 15m a. m. (second day after a 4-day fast) on the contrary, contained 10.4 grams of air-dry matter or about 50 per cent of the total.

Fluctuations of similar character, though not so marked, can be observed in the water content of the feces passed during the second nitrogen metabolism experiment.

Analysis of feces.—The air-dried feces for each week were ground, sampled, and analyzed. The amounts of nitrogen, sulphur, phosphorus, and the heat of combustion per gram are recorded in table 180.

TABLE 180.—*Determined weight of nitrogen, sulphur, and phosphorus, and heat of combustion of partially dried feces—Nitrogen metabolism experiments Nos. 1 and 2.*

Laboratory number.	Date.	(a) Nitrogen.[1]	(b) Phosphorus.	(c) Phosphoric acid (P_2O_5).	(d) Sulphur.	(e) Sulphur trioxide (SO_3).	(f) Heat of combustion per gram.
	Experiment No. 1:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
3889	First week, Mar. 14 to 21......	16.42	6.16	14.11	1.50	3.75	5.094
3890	Second week, Mar. 21 to 28....	27.17	8.52	19.51	2.49	6.21	5.146
3891	Third week, Mar. 28 to Apr. 4..	19.50	6.06	13.88	1.79	4.47	5.185
3892	Fourth week, Apr. 4 to 13.....	10.14	3.26	7.46	.98	2.44	5.059
	Experiment No. 2:						
3907	First week, Apr. 12[2] to 19......	17.22	6.83	15.65	1.57	3.93	4.779
3908	Second week, Apr. 19 to 26....	16.52	6.08	13.91	1.46	3.63	4.785

[1] The per cents of nitrogen in feces for the different weeks of the experiments were as follows: Experiment No. 1, first week, 4.16 per cent; second week, 4.09 per cent; third week, 4.40 per cent; fourth week, 4.82 per cent. For experiment No. 2, the corresponding per cents were 4.94 and 4.62.

[2] The separation of feces from nitrogen metabolism experiment No. 1 was not obtained until April 13. The second experiment, however, began on April 12, when food was ingested.

No attempt was made to determine the water in the feces, as the subject was not within the respiration chamber and consequently the water balance could not be determined. The analyses of the feces were accordingly made on the air-dry material.

Amounts of fecal nitrogen excreted per day.—Although it is obviously impossible to separate the feces for each experimental day, it is of advantage

to estimate as nearly as possible the quantity of fecal nitrogen excreted each day in order to compute the daily gains or losses of nitrogen to the body. Separation of the feces was made each week. In the computations of the amount of daily fecal nitrogen recorded in table 181 it is assumed that the

TABLE 181.—*Calculated daily excretion of fecal nitrogen—Nitrogen metabolism experiments Nos. 1 and 2.*

Date.	(a) Daily proportion of total nitrogen ingested per week.	(b) Calculated daily excretion of fecal nitrogen.
Experiment No. 1.		
First week:	*Per cent.*	*Grams.*
Mar. 14–15	13.9	2.28
Mar. 15–16	17.0	2.79
Mar. 16–17	14.6	2.40
Mar. 17–18	10.1	1.66
Mar. 18–19	17.8	2.92
Mar. 19–20	11.6	1.91
Mar. 20–21	15.0	2.46
Total, 1st week	100.0	16.42
Average per day	.....	2.35
Second week:		
Mar. 21–22	14.5	3.94
Mar. 22–23	13.0	3.53
Mar. 23–24	9.9	2.69
Mar. 24–25	14.1	3.83
Mar. 25–26	13.6	3.70
Mar. 26–27	16.8	4.56
Mar. 27–28	18.1	4.92
Total, 2d week	100.0	27.17
Average per day	.....	3.88
Third week:		
Mar. 28–29	13.7	2.67
Mar. 29–30	10.5	2.05
Mar. 30–31	9.7	1.89
Mar. 31–Apr. 1	20.3	3.96
Apr. 1–2	18.6	3.63
Apr. 2–3	15.7	3.06
Apr. 3–4	11.5	2.24
Total, 3d week	100.0	19.50
Average per day	.....	2.79
Fourth week:	*Per cent.*	*Grams.*
Apr. 4–5	22.4	2.27
Apr. 5–6	28.6	2.90
Apr. 6–7	28.7	2.91
Apr. 7–8	20.3	2.06
Total, 4 days	100.0	10.14
Average per day	.....	2.54
Experiment No. 2.		
First week:		
Apr. 12–13	5.2	0.90
Apr. 13–14	11.8	2.03
Apr. 14–15	14.6	2.51
Apr. 15–16	17.3	2.98
Apr. 16–17	15.8	2.72
Apr. 17–18	21.1	3.63
Apr. 18–19	14.2	2.45
Total, 1st week	100.0	17.22
Average per day	.....	2.46
Second week:		
Apr. 19–20	14.0	2.31
Apr. 20–21	16.7	2.76
Apr. 21–22	14.9	2.46
Apr. 22–23	11.0	1.82
Apr. 23–24	15.9	2.63
Apr. 24–25	14.9	2.46
Apr. 25–26	12.6	2.08
Total, 2d week	100.0	16.52
Average per day	.....	2.36

fecal nitrogen was proportional to the nitrogen ingested each day. The total nitrogen ingested each week was taken as 100 per cent and the proportion of this amount ingested each day calculated. These values are recorded in the first column of the table. The total nitrogen of the feces for the week was then

distributed among the different days in proportion to the nitrogen ingested. These apportionments are given in the second column of the table. The average fecal excretion of nitrogen per day for each week is also recorded.

Heat of combustion of food, feces, and urine.—The larger portion of the potential energy of the food ingested is either liberated in the form of heat as a result of oxidation in the body or stored as potential energy of body material, but a small portion of the potential energy of food leaves the body unoxidized in the organic matter of feces and urine. The proportion of the total energy unavailable for use by the body can be found by determining the heat of combustion of the organic matter of feces and urine. The determination of the heat of combustion of food or indeed of feces presents little difficulty, and as has been stated before the heat of combustion of the dry matter of food for each day and the feces for each week was determined on all the samples in these experiments. On the other hand, considerable difficulty is experienced in obtaining accurate results for the heat of combustion of urine and the process is much longer since the urine must be dried, preferably in a vacuum at room temperature. Many experiments made in this laboratory and indeed some experiments with this same subject S. A. B., have shown that the energy of the urine can be approximately computed by allowing 9 calories for every gram of urinary nitrogen. Hence in the experiments under discussion the energy of the urine was calculated by the use of this factor and the total nitrogen of the urine. Direct determinations of the heat of combustion of urine were made on a few samples.

Table 182 shows the determined heats of combustion of the food and feces, and the calculated heats of combustion of the urine, from which data the available energy (given in column *d*) for each day of the experiments is derived. As stated above the energy of the urine is calculated, and owing to the impracticability of making determinations on daily samples of feces the heat of combustion of the feces for each day has been obtained by means of the weight of partially dried material (table 179), and the heat of combustion per gram of the total for the week. Appended to the table are notes showing the few actual determinations of the heat of combustion of urine.

A comparison of the calculated amounts of energy in the urine with corresponding amounts actually determined shows not inconsiderable variations. For the purpose for which the energy of the urine is obtained, however, the errors involved make no material difference in the results. The largest error, 19 calories on March 18-19, constitutes only about 0.3 per cent of the total energy of food.

Analysis of urine.—The determinations in the urine that are of especial value in an experiment of this nature were made and the results are recorded in table 183. The weight, specific gravity, and volume are of interest for

comparison with similar data obtained with this subject during more or less prolonged periods of inanition. In many instances the phosphorus was determined both by titration with uranium acetate and by the method of fusion with sodium peroxide, and both sets of figures are given for comparison. The other determinations are presented in the same manner as for the fasting experiments.

TABLE 182.—*Energy of food, feces and urine—Nitrogen metabolism experiments Nos. 1 and 2.*

Date.	(a) In food (determined).	(b) In feces.[1]	(c) In urine (calculated) ($N \times 9.00$).	(d) Available energy [$a-(b+c)$].
Experiment No. 1.				
First week:	*Cals.*	*Cals.*	*Cals.*	*Cals.*
Mar. 14–15....	5,592	218	[2]113	5,261
Mar. 15–16....	6,771	291	119	6,361
Mar. 16–17....	4,857	119	100	4,638
Mar. 17–18....	3,943	49	57	3,837
Mar. 18–19....	6,527	582	[3]86	5,859
Mar. 19–20....	4,810	383	107	4,320
Mar. 20–21....	6,200	369	86	5,745
Total, 1st week	38,700	2011	668	36,021
Second week:				
Mar. 21–22....	5,611	665	92	4,854
Mar. 22–23....	6,092	640	84	5,368
Mar. 23–24....	4,598	390	72	4,136
Mar. 24–25....	4,847	357	78	4,412
Mar. 25–26....	6,786	572	[4]108	6,106
Mar. 26–27....	4,752	379	101	4,272
Mar. 27–28....	6,507	417	131	5,959
Total, 2d week	39,193	3420	666	35,107
Third week:				
Mar. 28–29....	3,874	340	113	3,421
Mar. 29–30....	3,440	334	83	3,023
Mar. 30–31....	3,446	410	81	2,955
Mar. 31–Apr. 2	4,357 4,356	389 306	[5]235	7,783
Apr. 2–3.......	3,798	256	115	3,427
Apr. 3–4.......	3,847	262	91	3,494
Total, 3d week	27,118	2297	718	24,103

Date.	(a) In food (determined).	(b) In feces.[1]	(c) In urine (calculated) ($N \times 9.00$).	(d) Available energy [$a-(b+c)$].
Fourth week:	*Cals.*	*Cals.*	*Cals.*	*Cals.*
Apr. 4–5......	3,395	318	114	2,963
Apr. 5–6......	4,640	388	104	4,148
Apr. 6–7......	4,208	208	[6]107	3,893
Apr. 7–8......	2,752	272	102	2,378
Total, 4 days..	14,995	1186	427	13,382
Experiment No. 2.				
First week:				
Apr. 12–13....	1,334	....	[7]100	1,234
Apr. 13–14....	2,806	334	105	2,367
Apr. 14–15....	3,573	349	136	3,088
Apr. 15–16....	3,300	136	125	3,039
Apr. 16–17....	3,362	300	149	2,913
Apr. 17–18....	5,621	209	161	5,251
Apr. 18–19....	3,768	339	114	3,315
Total, 1st week	23,764	1667	890	21,207
Second week:				
Apr. 19–20....	3,086	329	124	2,633
Apr. 20–21....	3,146	210	128	2,808
Apr. 21–22....	3,752	248	109	3,395
Apr. 22–23....	2,890	252	100	2,538
Apr. 23–24....	4,411	285	96	4,030
Apr. 24–25....	2,865	210	120	2,535
Apr. 25–26....	3,295	179	110	3,006
Total, 2d week	23,445	1713	787	20,945

[1] It has been assumed that the feces for a given day result from the food of the previous day; the feces from which the energy here given was calculated were excreted on the day following the one to which they are here assigned. Compare table 179, p. 293.
[2] Determined, 111 calories. [4] Determined, 115 calories. [6] Determined, 99 calories.
[3] Determined, 105 calories. [5] Determined, 244 calories. [7] Determined, 109 calories.

TABLE 183.—*Determinations in urine—Nitrogen metabolism experiments Nos. 1 and 2.*

Date.	(a) Weight of urine.	(b) Specific gravity	(c) Volume (a÷b).	(d) Nitrogen.	(e) Phosphorus[1]	Phosphoric acid (P_2O_5). (f) By fusion.	(g) By titration
Experiment No. 1.	*Grams.*		*c.c.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 14–15[2]	807.1	1.0183	793	12.61	0.642	1.470	1.656
Mar. 15–16[3]	769.8	1.0242	752	13.18	.952	2.180	2.196
Mar. 16–17[4]	1,460.8	1.0168	1,437	11.07	.744	1.704	1.268
Mar. 17–18	1,072.2	1.0162	1,055	6.31	.397	0.908	1.086
Mar. 18–19	1,818.5	1.0153	1,791	9.55	.867	1.987	1.978
Mar. 19–20	1,669.9	1.0172	1,642	11.89	.987	2.261	2.322
Mar. 20–21	1,667.7	1.0167	1,640	9.55	.895	2.050	2.118
Total, 1st week	9,266.0	....	9,110	74.16	5.484	12.561	12.624
Average per day	1,323.7	....	1,301	10.59	.783	1.794	1.803
Mar. 21–22[5]	1,312.3	1.0213	1,285	10.17	1.149	....	2.631
Mar. 22–23[6]	1,515.9	1.0212	1,484	9.35	1.084	....	2.482
Mar. 23–24	1,243.1	1.0210	1,218	8.02	.993	....	2.274
Mar. 24–25	1,349.4	1.0178	1,326	8.63	1.072	....	2.456
Mar. 25–26	1,133.6	1.0245	1,106	11.95	1.166	....	2.670
Mar. 26–27	913.5	1.0283	888	11.26	1.295	....	2.966
Mar. 27–28	1,229.5	1.0261	1,198	14.53	1.412	....	3.234
Total, 2d week	8,697.3	....	8,505	73.91	8.171	....	18.713
Average per day	1,242.5	....	1,215	10.56	1.167	....	2.673
Mar. 28–29	1,880.0	1.0142	1,854	12.54	1.559	....	3.571
Mar. 29–30	1,600.2	1.0144	1,577	9.27	1.100	....	2.513
Mar. 30–31	1,464.1	1.0144	1,443	9.00	1.150	....	2.635
Mar. 31–Apr. 2	3,534.9	1.0168	3,477	26.14	2.908	....	6.660
Apr. 2–3	1,910.7	1.0144	1,884	12.77	1.510	....	3.459
Apr. 3–4	1,596.7	1.0145	1,574	10.11	1.240	....	2.840
Total, 3d week	11,986.6	....	11,809	79.83	9.467	....	21.678
Average per day	1,712.4	....	1,687	11.40	1.352	....	3.097
Apr. 4–5	1,622.4	1.0126	1,602	12.65	1.280	....	2.934
Apr. 5–6	1,433.1	1.0152	1,412	11.56	1.350	....	3.093
Apr. 6–7	1,780.8	1.0142	1,756	11.87	1.251	2.866	2.992
Apr. 7–8	1,134.3	1.0200	1,112	11.36	.944	....	2.162
Total, 4 days	5,970.6	....	5,882	47.44	4.825	....	11.181
Average per day	1,492.7	....	1,471	11.86	1.206	....	2.795
Experiment No. 2.							
Apr. 12–13[7]	891.0	1.0160	877	11.14	0.652	1.493	1.671
Apr. 13–14[8]	1,006.8	1.0173	990	11.65	.499	1.142	1.375
Apr. 14–15	1,011.7	1.0203	992	15.08	.971	2.225	2.458
Apr. 15–16	1,426.2	1.0136	1,407	13.89	.956	2.189	2.067
Apr. 16–17	2,296.2	1.0121	2,269	16.53	1.307	2.994	2.731
Apr. 17–18	2,440.5	1.0153	2,404	17.93	1.432	3.280	3.752
Apr. 18–19[9]	1,834.9	1.0129	1,812	12.72	1.079	2.472	2.799
Total, 1st week	10,907.3	....	10,751	98.94	6.896	15.795	16.853
Average per day	1,558.2	....	1,536	14.13	.985	2.256	2.408

[1] Phosphorus from results by titration when fusion not available.
[2] Total creatinine, 1.566 grams; preformed creatinine, 1.493 grams; creatine, 0.073 gram.
[3] Preformed creatinine, 1.433 grams.
[4] Preformed creatinine, 1.251 grams.
[5] Preformed creatinine, 1.487 grams.
[6] Preformed creatinine, 1.523 grams.
[7] Total creatinine, 1.450 grams; preformed creatinine, 1.407 grams; creatine, 0.043 gram.
[8] Total creatinine, 1.420 grams; preformed creatinine, 1.384 grams; creatine, 0.036 gram.
[9] Total creatinine, 1.834 grams; preformed creatinine, 1.300 grams; creatine, 0.034 gram.

TABLE 183.—*Determinations in urine*—Continued.

Date.	(a) Weight of urine.	(b) Specific gravity.	(c) Volume (a÷b).	(d) Nitrogen.	(e) Phosphorus[1]	Phosphoric acid (P_2O_5). (f) By fusion.	(g) By titration.
Experiment No. 2—Cont'd.	*Grams.*		*c.c.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 19–20	1,840.0	1.0148	1,813	13.80	1.141	2.612	2.946
Apr. 20–21	1,937.0	1.0142	1,910	14.18	1.100	2.521	2.972
Apr. 21–22	1,896.4	1.0131	1,872	12.09	1.303	2.984	3.249
Apr. 22–23	2,417.9	1.0112	2,391	11.13	1.464	3.354	3.202
Apr. 23–24	1,497.1	1.0143	1,476	10.66	.994	2.277	2.460
Apr. 24–25	2,189.2	1.0136	2,160	13.30	1.629	3.732	3.372
Apr. 25–26	1,674.2	1.0155	1,649	12.19	....	....	3.743
Total, 2d week	13,451.8	....	13,271	87.35	[8] 7.631	[8] 17.480	21.944
Average per day	1,921.7	....	1,896	12.48	[8] 1.272	[8] 2.913	3.135

Date.	(h) Sulphur.	Sulphur trioxide (SO_3). (i) Total.	(j) Inorganic and ethereal.	(k) Neutral.	(l) Chlorine.	(m) Sodium chloride.
Experiment No. 1.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 14–15[2]	0.977	2.440	2.174	0.266	1.181	1.948
Mar. 15–16[3]	.872	2.176	1.854	.322	1.804	2.977
Mar. 16–17[4]	.650	1.622	1.411	.211	7.980	13.171
Mar. 17–18	.451	1.126	.867	.259	5.010	8.272
Mar. 18–19	.736	1.838	1.496	.342	6.225	10.275
Mar. 19–20	.752	1.876	1.634	.242	8.664	14.296
Mar. 20–21	.709	1.769	1.508	.261	7.570	12.490
Total, 1st week	5.147	12.847	10.944	1.903	38.434	63.429
Average per day	.735	1.835	1.563	.272	5.491	9.061
Apr. 6–7	0.764	1.906	1.647	0.259	....	....
Apr. 7–8	....	....	1.565	....	....	....
Experiment No. 2.						
Apr. 12–13[5]	0.812	2.026	1.803	0.224	1.725	2.847
Apr. 13–14[6]	.967	2.412	2.179	.233	4.075	6.724
Apr. 14–15	1.010	2.524	2.158	.366	2.313	3.816
Apr. 15–16	.826	2.063	1.853	.209	2.117	3.494
Apr. 16–17	1.016	2.536	2.384	.152	4.807	7.932
Apr. 17–18	1.023	2.555	2.313	.242	10.062	16.605
Apr. 18–19[7]	.814	2.033	1.877	.156	4.562	7.529
Total, 1st week	6.468	16.149	14.567	1.582	29.661	48.947
Average per day	.924	2.307	2.081	.226	4.237	6.992
Apr. 19–20	.772	1.927	1.753	0.174	4.025	6.642
Apr. 20–21	1.067	2.662	2.339	.323	4.538	7.487
Apr. 21–22	.788	1.968	1.751	.217	....	....
Apr. 22–23	.790	1.973	1.760	.213	....	....
Apr. 23–24	.681	1.700	1.639	.061	....	....
Apr. 24–25	.947	2.364	2.276	.088	....	....
Apr. 25–26	....	....	1.997	....	....	....
Total, 2d week	[8] 5.045	[8] 12.594	13.515	[8] 1.076	....	....
Average per day	[8] .841	[8] 2.099	1.931	[8] .179	....	....

[1] Phosphorus from results by titration when fusion not available.
[2] Total creatinine, 1.566 grams; preformed creatinine, 1.493 grams; creatine, 0.073 gram.
[3] Preformed creatinine, 1.433 grams.
[4] Preformed creatinine, 1.251 grams.
[5] Total creatinine, 1.450 grams; preformed creatinine, 1.407 grams; creatine, 0.043 gram.
[6] Total creatinine, 1.420 grams; preformed creatinine, 1.384 grams; creatine, 0.036 gram.
[7] Total creatinine, 1.334 grams; preformed creatinine, 1.300 grams; creatine, 0.034 gram.
[8] Six days only.

PART 3. DISCUSSION OF RESULTS.

The data accumulated in the experiments made on fasting men in this laboratory furnish material for a general discussion of the subject of the influence of inanition on metabolism. Of the numerous questions in physiology upon which these results throw light, it will obviously be impossible in this volume to discuss any except those which have more specifically to do with the general subject of metabolism. Numerous important subjects in metabolism, such as the protein requirement of the body and the relation of the active mass of protoplasmic tissue to the heat production, must be deferred for subsequent discussion. Certain aspects of the influence of inanition on metabolism, however, may with propriety be dealt with now and the following discussion is designed to present all the information thus far obtained regarding the various phases of physiological activity upon which the data throw light.

Literature.[1]—Where reference to the earlier literature on experiments with fasting men is made, the articles given in the following list will be indicated by the number preceding each title, as for example, Luciani (4).

(1) On the body-weight and urea in a case of starvation. David Nicholson. Brit. Med. Journ. (1870), 1, p. 4.

(2) Metabolism in fasting. A. Sadovyen. Russian Society of General Hygiene (1887-1888), 12, pp. 13-76.

(3) Observations on the metabolism of man during starvation. D. Noël Paton and Ralph Stockman. Proceedings of the Royal Society of Edinburgh (1888-1889), 16, p. 121.

(4) Das Hungern. Luigi Luciani (1890). Leipzig.

(5) Die Eiweisszersetzung beim Menschen während der ersten Hungertage. W. Prausnitz. Zeitschrift f. Biologie (1892), 29, p. 151.

(6) Il ricambio materiale e la tossicitá dell' urina nell' inanizione dell' uomo. G. Ajello & A. Solaro. La Riforma Medica (1893), Anno IX, 2, p. 542.

(7) Untersuchungen an zwei hungernden Menschen. Curt Lehmann, Friedrich Mueller, Immanuel Munk, H. Senator, N. Zuntz. Archiv f. pathologische Anatomie u. Physiologie u. f. klinische Medicin (1893), 131, Supplementheft.

(8) Metabolism during fasting in hypnotic sleep. C. F. Hoover and Torald Sollman. Journ. Exper. Med. (1897), 2, p. 403.

(9) Beiträge zur Kenntniss des Stoffwechsels beim hungernden Menschen. J. E. Johansson, E. Landergren, Klas Sondén, und Robert Tigerstedt. Skand. Archiv f. Physiologie (1897), 7, p. 29.

(10) Beiträge zum Stoffwechsel im Hungerzustande. E. Freund und O. Freund. Wiener klinische Rundschau (1901), 15, pp. 69-71 and 91-93.

(11) Beobachtungen über die Kreatininausscheidung beim Menschen. C. J. C. Van Hoogenhuyze and H. Verploegh. Zeitschrift für physiologische Chemie (1905), 46, p. 415.

(12) Eiweisszerfall und Acidosis im extremen Hunger mit besonderer Berücksichtigung der Stickstoffvertheilung im Harn (nach Untersuchungen an dem Hungerkünstler Succi). Theodor Brugsch. Zeitschrift f. expt. Pathologie u. Therapie (1905), 1, p. 419.

[1] The excellent article by C. von Noorden on Fasting and Chronic Starvation (Metabolism and Practical Medicine, Vol. II, Pathology, pp. 1-61; Keener & Co., Chicago, 1907) contains much of interest regarding metabolism during inanition.

EXPERIMENTS DURING INANITION.

BODY-WEIGHT.

Aside from the general observations on fasting individuals, such as the visible loss of flesh, strength, etc., perhaps the earliest measurement was that of the loss in body-weight. Since in fasting the body subsists upon its own tissues, it persistently loses in weight. It is to be regretted that in the majority of the earlier experiments, more careful consideration was not given to the weighings, accuracy of the scales used, uniformity in the amount of clothing worn, etc. The records of loss in body-weight from day to day are therefore in most instances very unsatisfactory, although in a few cases they were seemingly made with care.

The extreme accuracy of the weighing apparatus used in this laboratory tends to make the weighings of more than ordinary value. Moreover, verification of the changes in body-weight was secured in the experiments reported in the preceding sections by comparing them with the balance of income and outgo. It is therefore reasonable to suppose that the records of body-weight and changes of body-weight here given are much more accurate than any earlier records.

In instances of so-called complete fasting, i. e., where no drinking-water is consumed, the loss in body-weight might be expected to be larger than in those experiments in which water was taken, although the drinking of large quantities of water is almost immediately compensated by the voiding of large quantities of urine. In the complete fasting experiments, the only intake is the oxygen of the air. This intake varies from 500 to 600 grams per day, according to the muscular activity and size of the subject. Since this oxygen combines with carbon and hydrogen in the body, and with the disintegration of the body tissue there is a consequent loss of water, it is to be expected that the loss in body-weight during complete fasting will be not far from 700 to 1000 grams per day.

Experiments on animals have shown that with mammals, birds, amphibia, and fishes, the loss reached 40 per cent of the original weight before death ensued. Although numerous cases of fasting insane and pathological instances of long fasting are recorded, no satisfactory evidence has been accumulated to show the extent of the loss which the body can undergo before death ensues in the case of men. Apparently authentic instances are recorded, however, of professional fasters who succeeded in fasting from 30 to 45 (?) days and again recovered their usual health. During these latter tests of endurance, water was taken in every instance.

Possibly the most accurate of the earlier studies of loss of body-weight during complete fasting is that of Laun[1] in an experiment on himself lasting 21½ hours. From the completion of the evening meal at 10 o'clock February 19

[1] Untersuchungen zur Naturlehre des Menschen und der Thiere. Herausgegeben von J. Moleschott. Frankfurt a. M. (1857), p. 278.

until $5^h\ 30^m$ a. m., February 21, neither food nor drink was taken. He weighed himself at $7^h\ 30^m$ a. m., February 20, and again at 5 a. m., February 21. During this period the body-weight was reduced from 77.64 kg. to 75.77 kg., that is, in 21½ hours there was a loss in weight of 1.87 kg. The author calculates that for 24 hours the total loss in weight would have amounted to 2.09 kg. and that if he had weighed himself immediately after the evening meal on the 19th, the loss for the entire period would have been 2.34 kg. The balance used was accurate to 45 grams.

In the three 24-hour fasting experiments reported by Pettenkofer and Voit[2] the losses in body-weight were 930, 660, and 680 grams, respectively. In the last experiment work was performed.

Ranke[3] lost 1.130 grams in weight in a 24-hour fast with no water. Observations began 24 hours after the last meal, and consequently corresponded to those on the second fasting day.

Nicholson (1) made observations on a fasting prisoner whose body-weight at the beginning was 107½ pounds and 100½ pounds on the sixth day, after a small portion of food had been taken. According to the statement of the author, there was absolute fast from the commencement up to the fifth day, during which period there was a loss of 7 pounds (3.2 kg.). At the end of the third day the loss was 5 pounds or an average loss of 1.7 pounds per day. On the fourth day the subject lost 1 pound and during the fifth day the author estimates that he lost 1 pound although weighings were not made. Assuming a loss of 1 pound on the fifth day, there was an average daily loss of 1.4 pounds during the period of starvation, the greatest loss appearing during the first part of the experiment.

Müller[4] reports a case of fasting caused by œsophagus stenosis, in which the body-weight on the sixth of July was 34.5 kilos, and on the ninth of July was 33 kilos. These 4 days, which represented the fifth to eighth day of complete inanition, resulted, therefore, in the loss to the body of 1.5 kg. The body-weight of the subject, however, was much below the normal.

Schaefer[5] reports the body weights of a number of insane persons who fasted. One woman 51 years old, weighing about 68 kg., fasted from March 3 to March 8, but drank 500 cc. of water per day. On March 6, the body-weight was 63.3 kg. and on March 7 it was 63.3 kg. A second case was that of a woman 57 years old, weighing 56 kg., who fasted from March 19, drinking only a little water and clear cold coffee. On March 23, the body-weight was 49.3 kg., on the 24th, 48.8 kg., and on the 25th, 48 kg.

Another instance was that of a woman weighing 41.2 kg., who fasted from April 28 until May 4. No water nor food was consumed. On the second of May the body-weight was 38.7 kg., and on May 3, 37.85 kg.

[2] Zeit. f. Biol. (1866), **2**, p. 479.
[3] Die Ernährung des Menschen (1876), p. 211.
[4] Zeit. f. klin. Medicin (1889), **16**, p. 496.
[5] Allgem. Zeit. f. Psychiatrie (1897), **53**, p. 525.

The fourth case was that of a woman 40 years old. weighing 45.3 kg. From August 15, no water nor food was taken. On August 17 the body-weight was 38.2 kg., and on August 19, 36.2 kg.

The fifth subject was 32 years old, and weighed 38.5 kg. No food was taken after September 19, although water was consumed in small quantities. On September 22, the body-weight was 36.1 kg.

In the sixth instance, a woman 20 years old, weighing 56 kg. fasted from October 13 to 18, taking neither food nor water. At the end of the fast, the body-weight was 46.3 kg.

The seventh instance reported was that of a woman 50 years old, who weighed 38 kg. at the beginning of her fast. From July 5 to 9, she abstained completely from food and water. At the end of the 4 days, the body-weight was 33 kg.

A fast reported to have been made by Tanner and lasting 45 days showed a change of body-weight from 71.7 kg. at the beginning to 60.0 kilos at the end of 25 days.* During the first 16 days, the account states that Tanner pretended to drink no water, though he rinsed his mouth with it from time to time. In this period he lost weight rapidly. After the sixteenth day, drinking-water was taken as desired and it is stated that he actually gained $4\frac{1}{2}$ pounds in weight during the next 4 days, after which time he again commenced to lose weight.

TABLE 184.—*Losses of body-weight by fasting subjects.*

Day of fast.		J. A.	Cetti.	Breit-haupt.	Lander-gren.[1]	J.[2]
Initial weight	Kilos	67.80	57.00	60.07	78.60	80.17
Loss 1st day	Kilos	1.63	.55	.55	.60	[3]1.41
	Per cent	**2.43**	**.97**	**.92**	**.77**	**1.77**
Loss 2d day	Kilos	.92	.94	.63	1.77	1.20
	Per cent	**1.40**	**1.68**	**1.06**	**2.30**	**1.54**
Loss 3d day	Kilos	.75	1.08	.77	1.00	.91
	Per cent	**1.16**	**1.96**	**1.32**	**1.32**	**1.18**
Loss 4th day	Kilos	1.03	.98	.95	.80	1.53
	Per cent	**1.61**	**1.82**	**1.65**	**1.07**	**2.02**
Loss 5th day	Kilos	.68	.85	.20	....	....
	Per cent	**1.08**	**1.60**	**.35**	....	....
Loss 6th day	Kilos	....	.25	.52	....	....
	Per cent	....	**.48**	**.92**	....	....
Loss 7th day	Kilos	....	.00	....	....	....
	Per cent	....	**.00**	....	....	....
Loss 8th day	Kilos	....	.51	....	....	....
Loss 9th day	Kilos	....	.60	....	....	....
Loss 10th day	Kilos	....	.59	....	....	...

[1] Skan. Archiv. f. Physiol. (1903), 14, p. 112.
[2] Reported by A. Sadovyen.
[3] Subject ate this day 86 grams bread and 25.5 grams sugar and drank 200 grams tea.

Of the longer fasts in which the body-weights were recorded, those of Succi, as reported by Luciani (4) and Ajello & Solaro (6); Jacques, reported by Paton & Stockman (3); Cetti and Breithaupt, reported by Lehmann, Mueller, Munk, Senator, and Zuntz (7); the student J. A., reported by

*Cited by Paton & Stockman (3). British Med. Jour. (1880), 2, p. 171.

Johansson, Landergren, Sönden, and Tigerstedt (9); and Sohn, reported by Hoover & Sollman (8) are of the greatest interest.

In computing the losses of weight in the different experiments of earlier writers much difficulty was experienced because of deficiency of statement in many instances as to the time of day at which weights were taken, and as

TABLE 185.—*Losses of body-weight of Succi and Jacques in experiments without food.*

Day of fast.		Succi.				Jacques.[1]
		At Paris.	At Milan.	At Florence.	At Naples.	
Initial weight	Kilos	[2]63.00	[2]61.30	63.30	[2]63.60	62.008
Loss 1st day	Kilos	....	....	.90	....	1.333
	Per cent	....	....	1.43	....	2.17
Loss 2d day	Kilos	3.60	1.55	1.40	1.80	.935
	Per cent	5.88	2.56	2.27	2.87	1.55
Loss 3d day	Kilos	.40	.80	1.20	1.20	.510
	Per cent	.68	1.35	1.99	1.96	.86
Loss 4th day	Kilos	1.00	.75	[3]+.10	.80	[3]+.007
	Per cent	1.71	1.28	[3].17	1.33	[3] .01
Loss 5th day	Kilos	.60	.50	.60	.70	.262
	Per cent	1.04	.86	1.01	1.18	.44
Loss 6th day	Kilos	.30	.85	.65	.90	.623
	Per cent	.52	1.48	1.10	1.53	1.06
Loss 7th day	Kilos	.10	.55	[4]	.70	[3]+.198
	Per cent	.18	.97	[4]	1.21	[3] .34
Loss 8th day	Kilos	.10	.20	[4]	.40	1.870
Loss 9th day	Kilos	.90	.50	.40	.20	.454
Loss 10th day	Kilos	.30	.20	.55	[3]+.30	.000
Loss 11th day	Kilos	.40	1.00	.45	.70	.425
Loss 12th day	Kilos	1.30	.10	.65	.60	.198
Loss 13th day	Kilos	.80	.30	.35	.40	.936
Loss 14th day	Kilos	....	.40	.40	.10	.000
Loss 15th day	Kilos	....	.50	.25	.10	[3]+.369
Loss 16th day	Kilos	.30	.25	.30	.05	.057
Loss 17th day	Kilos	.20	.25	.20	.65	[3]+.085
Loss 18th day	Kilos	.30	.50	.45	.60	.255
Loss 19th day	Kilos	.30	.75	.45	.50	.878
Loss 20th day	Kilos	.30	.20	.40	.50	.000
Loss 21st day	Kilos	.40	.25	.20	.60	.114
Loss 22d day	Kilos	....	.00	.35	....	.455
Loss 23d day	Kilos	....	.30	.40	....	.367
Loss 24th day	Kilos	.55	.45	.40	....	.255
Loss 25th day	Kilos	.10	.45	[3]+.05	....	.284
Loss 26th day	Kilos	.10	.30	.20	....	.057
Loss 27th day	Kilos	.35	.40	.05	....	.509
Loss 28th day	Kilos	.15	.30	.20	....	[3]+.339
Loss 29th day	Kilos	.25	.20	.60	....	.367
Loss 30th day	Kilos	.50	.30	[3]+.75	....	.170

[1] Subject began drinking quantities of his urine on third day.
[2] Weight at beginning of second day. [3] Gained.
[4] Subject not weighed at beginning of the eighth day.

to whether the subjects were weighed with or without clothing. After a critical examination of the data, the computations of changes in weight were made. The results for the shorter fasts are recorded in table 184, in which are included also the percentage losses calculated on the weight from day to day.

The long series of observations made by Luciani (4) and Ajello & Solaro

(6) on the professional faster Succi, and the observations of Paton & Stockman (3) on the faster Jacques, were continued for 20 to 30 days. The observations on the body-weight of Succi, aside from the question as to the record of the exact beginning and end weights, are very carefully recorded. As pointed out by Paton & Stockman, the irregularities in the time of voiding the urine make the daily losses in weight of their subject somewhat uncertain. The daily losses of body-weight in these longer fasts of Succi and Jacques are recorded in table 185. The percentage losses for the first seven days are also given.

Aside from the longer experiments mentioned above, a 45-day fasting experiment with Succi is reported to have taken place in New York in 1890. His body-weight is stated to have fallen from 147¼ pounds (66.9 kilos) on November 5 to 104¾ pounds (47.6 kg.) on December 20.[7]

Daiber[7a] reported the losses in weight during a 20-day fast by Succi in 1896. The tabular statement shows a great regularity in the loss from day to day. The average loss was 490 grams; the initial weight was 71.7 kilograms.

Bönniger and Mohr[7b] give the losses in weight of a professional fasting woman during a 16-day fast. The subject was 48 years old, 1.52 meters high, and weighed at the beginning of the fast 56.3 kilograms. The total loss in weight was 8.1 kg., more than half of which was lost during the first six days.

In March, 1904, another fast of 31 days duration was made by Succi in Hamburg. Brugsch (12) reports that during this experiment, Succi lost 27 pounds (12.3 kg.), the original weight being 157 pounds (71.4 kg). This corresponds to a total loss in body-weight of 17.2 per cent. During this fast Succi drank regularly 750 cc. of carbonated water per day.

Sohn, the hypnotic subject of Hoover & Sollman (8), lost in body-weight from July 15 to July 23, 5.89 kg., the original body-weight being 129 pounds (58.6 kg.). During the first day and a half no water was taken, but about 900 cc. was furnished each day for the rest of the fast, which lasted 8 days. The records of weighings for the individual days were unsatisfactory and for this reason only the total loss for the experiment is reported.

A summarized statement of the losses of body-weight of the subjects in the fasting experiments made at Middletown is given in table 186. The losses in weight in experiment No. 59 were computed from the balance of income and outgo. With this exception the weights were all taken by means of a special platform scale, accurate to within 2 grams. Hence the weights are recorded to the third decimal place, and any errors in the gains or losses shown are not due so much to incorrect weighings as to lack of uniformity from day to day in the kind and number of articles which were weighed with the subjects, as for example clothing, etc.

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[7] I have been unable to find a record of this fast in any scientific journal and have to rely upon the newspaper reports as given in the N. Y. Tribune for November 6, 1890, and December 21, 1890. Written statements from several physicians in attendance on this fast show varying opinions regarding its authenticity.

[7a] Schweizerische Wochenschrift für Chemie und Pharmacie (1896), 34, pp. 395-399.

[7b] Zeit. f. Experimentelle Pathologie u. Therapie (1906), 3, p. 675.

TABLE 186.—*Body-weights*[1] *and losses of body-weight in metabolism experiments without food.*

[All weights taken at 7 a. m.]

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.
59	B. F. D., Dec. 18-21, 1903—No body weights taken	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.* ....
	Loss[2]	1.441	0.438	0.824	
68	A. L. L., Apr. 27-29, 1904	72.922 71.226	71.226 70.326		
	Loss	1.696	0.900		
69	A. L. L., Dec. 16-20, 1904	73.806 73.152	73.152 72.173	72.173 71.714	71.714 70.952
	Loss	0.654	0.979	0.459	0.762
71	S. A. B., Jan. 7-11, 1905	58.199 57.108	57.108 56.601	56.601 56.183	56.183 55.069
	Loss	1.091	0.507	0.418	1.114
73[3]	S. A. B., Jan. 28-Feb. 2, 1905	59.134 57.966	57.966 57.280	57.280 56.444	56.444 55.665
	Loss	1.168	0.686	0.836	0.779
75[4]	S. A. B., Mar. 4-11, 1905	59.520 59.476	59.476 58.753	58.753 58.068	58.068 57.174
	Loss	0.044	0.723	0.685	0.894
77	S. A. B., Apr. 8-12, 1905	61.612 60.876	60.876 59.686	59.686 58.184	58.184 57.316
	Loss	0.736	1.190	1.502	0.868
79	H. E. S., Oct. 13-15, 1905	57.170 56.081	56.081 54.823		
	Loss	1.089	1.258		
80	C. R. Y., Oct. 27-29, 1905	69.342 67.617	67.617 65.682		
	Loss	1.725	1.935		
81	A. H. M., Nov. 21-23, 1905	62.016 61.047	61.047 59.810		
	Loss	0.969	1.237		

[1] In experiments Nos. 68-77, weights include underclothing, 80, all clothing; in experiments Nos. 79 and 81 weights include no clothing.
[2] Computed from balance of income and outgo.
[3] Body-weights for fifth day of experiment No. 73, 55.665 — 54.997 kilos, loss 668 grams.
[4] Body-weights for fifth day of experiment No. 75, 57.174 — 56.724 kilos, loss 450 grams; sixth day, 56.724 — 56.333 kilos, loss 391 grams; seventh day 56.333 — 55.836 kilos, loss 497 grams.

TABLE 186.—*Body-weights*[1] *and losses of body-weight in metabolism experiments without food*—Continued.

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.
		Kilos.	*Kilos.*	*Kilos.*	*Kilos.*
82	H. C. K., Nov. 24–26, 1905..........	71.493 70.888	70.888 69.360		
	Loss.........................	0.605	1.528		
83	H. R. D., Dec. 5–7, 1905............	55.637 55.098	55.098 54.234		
	Loss.........................	0.539	0.864		
85	N. M. P., Dec. 9–11, 1905...........	67.625 66.127	66.127 65.297		
	Loss.........................	1.498	0.830		
89	D. W., Jan. 10–12, 1906............	[2] 79.063 [2] 77.561	[2] 77.561 [2] 76.581		
	Loss.........................	1.502	0.980		
	Average loss[3].............	1.054	1.004	0.787	0.883

[1] In experiments Nos. 82-89, weights include no clothing.
[2] Clothing assumed as weighing 2.2 kilos.
[3] Average loss for all fasting experiments, for the fifth day, 559 grams; sixth day, 391 grams, and seventh day 497 grams.

An inspection of the figures in table 186 shows marked variations in the losses of weight on the first day. This is true not only for different individuals but also for the same person in different experiments. For example, S. A. B. lost on the first day of experiment No. 71, 1.091 kg., while on the first day of experiment No. 75, he lost only 0.044 kg. The largest loss in weight on the first day was in experiment No. 80, amounting to 1.725 kg. On the second day of fasting, the losses in weight are more nearly equal than on the first day. This is particularly true of different experiments with the same subject, although it is to be noted that in experiment No. 71, S. A. B. lost 507 grams on the second day, while in experiment No. 77, he lost more than twice as much.

In the six experiments which lasted 3 days each, the loss on the third day is comparatively uniform, with the exception of experiment No. 77. The highest loss of any third day, namely 1.50 kg., occurred in this experiment. The average loss for the third day of the other 5 experiments is 0.644 kg.

Five experiments continued for 4 days or over and on the fourth day the loss is quite constant in all experiments. The average, however, is markedly greater than that on the third day. Four of the experiments were made on the same subject and the variations in body loss are much less than on any other day.

In two fasting experiments in which data were obtainable for the fifth day, the loss of weight was in one case 0.668 kg. and in the other 0.450 kg.

Only one of the fasting experiments continued for more than 5 days. In this instance the loss of body-weight was 0.391 kg. on the sixth and 0.497 kg. on the seventh day.

While, therefore, marked fluctuations in the loss of body-weight on the first, second, and third days of fasting are to be noted in practically every experiment, the loss on the fourth and succeeding days seems to be much more nearly uniform and judging from experiments Nos. 73 and 75, the average loss per day is not far from 0.57 kg.

TABLE 187.—*Daily percentage loss of body-weight in metabolism experiments without food.*[1]

Day of fast.	B. F. D.	A. L. L.		S. A. B.			
	Experiment 59.[2]	Experiment 68.[3]	Experiment 69.[3]	Experiment 71.[3]	Experiment 73.[3]	Experiment 75.[3]	Experiment 77.[3]
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	2.15	2.35	0.89	1.89	1.99	0.07	1.20
Second day	.66	1.27	1.35	.89	1.19	1.22	1.97
Third day	1.26	....	.64	.74	1.47	1.17	2.55
Fourth day	....	....	1.07	2.00	1.39	1.55	1.50
Fifth day	....	....	....	....	1.21	.79	....
Sixth day	....	....	....	....	....	.69	....
Seventh day	....	....	....	....	....	.89	....
Average	1.36	1.81	.99	1.38	1.45	.91	1.81

Day of fast.	H. E. S.	C. R. Y.	A. H. M.	H. C. K.	H. R. D.	N. M. P.	D. W.
	Experiment 79.[4]	Experiment 80.[5]	Experiment 81.[4]	Experiment 82.[4]	Experiment 83.[4]	Experiment 85.[4]	Experiment 89.[6]
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	1.92	2.52	1.57	0.85	0.97	2.24	1.92
Second day	2.27	2.90	2.05	2.18	1.58	1.26	1.27
Average	2.10	2.71	1.81	1.52	1.28	1.75	1.60

[1] Computed by dividing the loss of weight for any given 24 hours by the average of the body-weights at the beginning and end of the same 24 hours. The *average* is the sum of the percentages thus obtained divided by the number of days considered.

[2] Beginning weight assumed. See p. 47.

[3] Weights include underclothing.

[4] Weights without clothes.

[5] Weights include all clothing.

[6] Weights without clothes. See Table 186.

The irregularities in variations in body-weight in these experiments are very considerable but they are by no means so large as those observed in experiments with Succi and Jacques. (See table 185.) On some of the days in the long fasts with these men actual gains in body-weight have been recorded.

The most noticeable instance of a gain in weight is in that imperfectly reported experiment of Tanner in which it is stated that after having fasted for 16 days without water an actual gain of 4½ pounds followed the ingestion of water. In none of the fasting experiments reported here (table 186) was

there an actual gain in weight on any day. There was, however, a minimum loss of 44 grams on the first day of experiment No. 75.

A number of the earlier experimenters have computed the per cent of loss of weight from day to day in fasting experiments, by dividing the loss for each day by the corresponding body-weight. Unfortunately it is uncertain in several instances whether the initial body-weight for the day, the weight at the end of the day, or the average weight for the day was used.

Using the data of body-weights, the per cent of loss has been computed in such a manner that all the experiments are comparable. The losses in terms of per cent for the earlier experiments are recorded in tables 184 and 185 above, and for the Middletown experiments in table 187. No percentages are given beyond the seventh day of the different fasts.

TABLE 188.—*Daily cumulative percentage loss from original body weight in experiments with fasting subjects.*

Day of fast.	Succi. At Paris. 63.0 K.	At Milan. 61.8 K.	At Florence. 63.3 K.	At Naples. 63.6 K.	Jacques. 62.0 K.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	[1]....	[1]....	1.42	[1]....	2.15
Second day	5.71	2.53	3.63	2.83	3.66
Third day	6.35	3.83	5.53	4.72	4.48
Fourth day	7.94	5.06	[2]5.37	5.98	[2]4.47
Fifth day	8.89	5.87	6.32	7.08	4.89
Sixth day	9.37	7.26	7.35	8.49	5.90
Seventh day	9.52	8.16	[3]....	9.59	[2]5.58

Day of fast.	J. A. 67.8 K.	Cetti. 57.0 K.	Breithaupt. 60.1 K.	Landergren. 78.6 K.	J. 80.2 K.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	2.40	0.97	0.92	0.76	[5]1.76
Second day	3.76	2.61	1.96	3.02	3.26
Third day	4.87	4.51	3.25	4.29	4.39
Fourth day	6.39	6.13	4.83	5.31	6.30
Fifth day	7.39	7.72	5.16	....	....
Sixth day	....	8.16	6.03	....	....
Seventh day	....	[4]8.16	....	....	....

[1] Beginning weight of second day used in calculations.
[2] Subject gained in weight.
[3] Subject not weighed at beginning of eighth day.
[4] No loss the seventh day.
[5] Subject ate this day 86 grams bread and 25.5 grams sugar and drank 200 grams tea.

The cumulative loss in weight as the fast progresses expressed in per cent of the original weight, has frequently been used by others in discussing the loss in body-weight during fasting. Hence the total loss at the end of each day expressed in per cent of the initial body-weight is given for the earlier experiments in table 188. Similar computations for the Middletown experiments are shown in table 189.

While Falck[a] in his work on dogs and later Luciani (4) in reporting his experiment with Succi have considered at length the possibilities of a mathematical relation between the loss in weight and the length of the fast it is clear that at least so far as experiments on man are concerned, when accurate records of body-weight are made and computations of the percentage loss per day are recorded, very little regularity in the losses in weight appears. The loss in weight is affected not only by variations in the weight of urine,

TABLE 189.—*Daily cumulative percentage loss from original body weight in metabolism experiments without food.*

Day of fast.	B. F. D.	A. L. L.		S. A. B.			
	Experiment 59.[1] 67.8 K.	Experiment 68.[2] 72.9 K.	Experiment 69.[2] 73.8 K.	Experiment 71.[2] 58.2 K.	Experiment 73.[2] 59.1 K.	Experiment 75.[2] 59.5 K.	Experiment 77.[2] 61.6 K.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	2.13	2.33	0.89	1.87	1.98	0.07	1.19
Second day	2.77	3.56	2.21	2.75	3.14	1.29	3.13
Third day	3.99	....	2.83	3.46	4.55	2.44	5.56
Fourth day	....	....	3.87	5.38	5.87	3.94	6.97
Fifth day	....	....	....	....	7.00	4.70	....
Sixth day	....	....	....	....	....	5.35	....
Seventh day	....	....	....	....	....	6.19	....

Day of fast.	H. E. S.	C. R. Y.	A. H. M.	H. C. K.	H. R. D.	N. M. P.	D. W.
	Experiment 79.[3] 57.2 K.	Experiment 80.[4] 69.3 K.	Experiment 81.[2] 62.0 K.	Experiment 82.[3] 71.5 K.	Experiment 83.[3] 55.6 K.	Experiment 85.[3] 67.6 K.	Experiment 89.[5] 79.1 K.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
First day	1.90	2.49	1.56	0.85	0.97	2.22	1.90
Second day	4.11	5.28	3.56	2.98	2.52	3.44	3.14

[1] Beginning weight assumed from weighing of later date, includes underclothing.
[2] Weights include underclothing.
[3] Weights without clothes.
[4] Weights include all clothing.
[5] Weights without clothes.

water of respiration and perspiration, and carbon dioxide, but also by the water ingested. Furthermore, it is highly probable that temperature, muscular activity, state of bodily condition and other more or less obscure factors all contribute toward the balance between income and outgo in such a manner as to cause the marked fluctuations in body-weight appearing on different days. Hence it is obvious that losses in body-weight in experiments of but few days duration are wholly without significance.

With regard to the total cumulative loss as the experiment progresses, it appears that in the long experiments of Succi the loss bears in general a direct ratio to the length of the experiment.

[a] Beiträge z. Physiol., Hyg., Pharm. u. Toxikol. (1875).

BODY TEMPERATURE.

Since muscular activity has a very pronounced and immediate effect on the body temperature, experiments during fasting when the internal muscular activity due to peristalsis is at a minimum are of especial interest. In connection with the earlier fasting experiments made in this laboratory,[9] observations regarding body temperature were made and in some instances curves were drawn showing the body temperature for 24 hours. These curves together with a large number of other curves of body temperature were published accompanied by a special discussion of the fluctuations in body temperature.[10]

The most noticeable effect of fasting on the normal body temperature curve seems to be a flattening of the curve during the waking hours, although in the few experiments made, the evening fall especially after retiring and the early morning rise were, if anything, more marked than the normal temperature fluctuations at the same hours. The night curves for a number of fast days were also studied, and the general conclusion was that fasting results in a slight lowering of the average body temperature, amounting, however, to but a few tenths of a degree. This is in harmony with the observations of Jurgensen[11] who, not only finds the average body temperature somewhat lower during fast, but also notes a smaller amplitude of the daily curve.

Although no temperature observations were recorded by Nicholson (1) he states that there was no fever during the fast of the prisoner under his care.

In the fast made by Tanner,[12] no fall in temperature was noticed. The temperature taken in the mouth was 36.9° on the 25th day and 37.1° on the 30th day. As has been pointed out previously, this fast was very imperfectly reported and its authenticity is somewhat in doubt.

Noyes[13] observed a temperature of 34.4° in an insane man who had consumed no food for 45 days. Pembrey[14] points out in commenting on this, that this subject was paralyzed in the lower limbs.

In the report of the observations made by Schaefer[15] on the fasting insane it is stated that the body temperature was normal in all cases.

Paton & Stockmann (3) record that during the fast of Jacques his temperature was invariably subnormal ranging from 35.6° to 34.1° C. During a slight attack of gout, on the 16th day, the temperature ranged from 36.0° to 36.6°.

During the fasting experiment with Cetti (7) in Berlin, the temperature observations were made in the axilla twice a day. One observation is recorded on the day preceding the fast and one on the following food day. The average body temperature for the 10 fasting days is 36.7°, which is, however, somewhat higher than the observations made before and after the experiment.

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[9] U. S. Dept. of Agric., Office of Expt. Sta. Bul. 136 (1903).
[10] Benedict & Snell. Archiv f. d. ges. Physiol. (1902), **90**, p. 33.
[11] Die Körperwärme des Gesunden Menschen, Leipsic, 1873.
[12] British Medical Journ., London (1880), **2**, p. 171.
[13] British Medical Journal, London (1880), **2**, p. 557.
[14] Schaefer's Physiology, **1**, p. 810.
[15] Allgem. Zeit. f. Psychiatrie (1897), **53**, p. 525.

With Breithaupt, the second subject of the Berlin experiments (7) the temperature was taken, presumably in the axilla, morning and evening. No records were shown for the day with food preceding the fast, but temperature records were given for the first food day after the fast. The tendency for the temperature to decrease slowly as the fast progresses is noted, but after the resumption of the ingestion of food it was not overcome.

The body temperature of the subject J. A. (9) was taken every 2 hours during the waking period. This is true for both the fasting and the food periods. The average temperature for the 3 days with food was 37.39°, while the average temperature of 5 days fasting was 37.23°. The average daily temperatures of the 5-day fast were 37.20°, 37.27°, 37.22°, 37.13°, and 37.23°, respectively.

Body temperature observations were made by Hoover and Sollman (8) on their hypnotic subject during the 8 days of the experiment. It was not stated how the observations were made. A slight tendency for the average temperatures to fall as the fast progressed is noticeable and in general the evening fall and morning rise are readily recognized on the temperature curve. The average temperatures for the succeeding days of the fast were: 36.6°, 36.8°, 36.7°, 36.6°, 36.3°, 36.4°, 36.3°, 36.2°.

In only one of the longer fasts made by Succi were the temperature fluctuations accurately observed and recorded. Luciani (4), in the Florence fast, made temperature observations in the left axilla throughout the fast. The highest temperature recorded was on the 23d day, 37.25°. The lowest temperature was on the seventh day, 36.2°. No tendency for the temperature to fall as the fast progressed was observed.

The newspaper report of the medical bulletin issued by the attending physicians on the 45th day of the uncertain New York fast states that the temperature was normal. No temperature records of this fast have been published.

In considering many of the earlier temperature observations on fasting subjects it is extremely difficult to give suitable value to the different observations owing to the fact that little regularity is exhibited by different observers as regards the method of taking body temperatures. It is of very great importance to know whether the temperature was taken in the mouth, axilla, or rectum. Unfortunately, in many of the cases recorded, the normal body temperatures of the subjects, i. e., when subsisting on an ordinary diet, were not recorded and hence the data are missing for an accurate study of the question as to whether fasting actually lowers the average body temperature.

The body temperatures recorded in the Middletown experiments were ordinarily taken in the rectum by means of an electrical resistance thermometer.[a]

[a]Archiv f. d. ges. Physiologie (1901), 88, p. 492.

In a few instances the temperature observations were taken by clinical thermometers, in which case they are noted in table 190, and in no cases are they included in the averages. The temperature measurements are based upon the absolute international hydrogen thermometer scale.

In the majority of experiments here reported, temperature observations by means of the rectal thermometer were continuously obtained. Contrary to the experience of practically all the fasting subjects, S. A. B., the subject of the longer experiments, was extremely uncomfortable when wearing the rectal thermometer. Unfortunately, therefore, the records during the longer fasts were but imperfectly taken.

For the specific purpose of determining the total heat production, the body temperature at the end of each experimental period is of especial importance. Reserving for discussion in another publication the temperature fluctuations from hour to hour and from minute to minute, only the actual temperature observations at the end of each experimental period are recorded in this place. The results are presented in table 190, and for purposes of comparison the few observations made during experiments with food are also given.

Under normal conditions the maximum temperature occurs late in the afternoon. The temperature then falls rapidly during the evening and reaches the minimum between 3 and 5 o'clock in the morning, after which it rises rapidly for 2 or 3 hours.[17] The results obtained during the fasting experiments here reported show that even during fasting the body temperature generally follows the normal course. While the difference between the minimum and maximum temperature for the day with normal individuals with food is about 1° C., in the majority of the fasting experiments here reported this amplitude is very much less.[18] The average difference for all Middletown fasting experiments is not far from 0.5 degree. This is wholly in accord with the observations noted previously in this laboratory. The general effect of fasting on the absolute body temperature can best be studied in the longer fasting experiments, for if the contention is made that as the fast progresses there is a tendency for the body temperature to fall, this should be especially noticeable in fasts of long duration. An examination of the average temperatures for the day shows that there is no such tendency exhibited during the experiments here reported, although the verification of the statement is not easy owing to deficient data. It is clear, however, that in experiments of 7 days or less there is no indication that fasting lowers body temperature. This is in agreement with the observations made by Paton and Stockman (3) on

[17] Benedict & Snell. Loc. cit.

[18] On the 6th and 29th days of Succi's Florence fast, Luciani made temperature observations in the axilla from hour to hour during the day and night. The fluctuations thus measured are not far from the normal. As Luciani states, however, Succi's sleep was much disturbed by the observers.

TABLE 190.—*Body temperature by rectal thermometer—Metabolism experiments with and without food.*

Experiment number, subject, and date.	7 a.m.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	7 p.m.	9 p.m.	11 p.m.	1 a.m.	3 a.m.	5 a.m.	Average.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
59. B. F. D.													
Dec. 18-19, 1903	36.72	36.80	36.84	36.75	36.80	36.84	36.94	36.67	36.44	36.35	36.42	36.45	36.67
Dec. 19-20, 1903	36.56	36.84	36.87	36.83	36.80	36.93	36.73	36.84	36.40	36.45	36.52	36.67	36.70
Dec. 20-21, 1903	36.73	36.93	36.85	36.99	37.13	37.01	37.01	36.91	36.54	36.41	36.40	36.54	36.79
Average per day	36.67	36.86	36.85	36.86	36.91	36.93	36.89	36.81	36.46	36.40	36.45	36.55	36.72
68. A. L. L.													
Apr. 27-28, 1904	[1]37.22	....	....	....	....	....	[1]37.22	....	....	....	....	....	[1]37.22
Apr. 28-29, 1904	[1]37.50	....	....	....	....	...	[1]37.28	....	....	....	....	....	[1]37.39
69. A. L. L.													
Dec. 16-17, 1904	36.72	36.66	36.32	36.48	36.68	36.68	36.91	36.80	36.67	36.30	36.50	36.52	36.60
Dec. 17-18, 1904	36.78	36.61	36.96	36.72	37.19	37.11	37.45	37.26	37.23	36.82	36.62	36.61	36.95
Dec. 18-19, 1904	36.81	37.02	36.99	37.19	36.98	36.97	37.04	36.86	36.63	37.18	....	....	36.97
Dec. 19-20, 1904	[2]36.57	36.39	36.63	36.80	36.76	36.83	36.87	36.79	36.51	36.41	36.33	36.36	36.60
Average per day	36.72	36.67	36.73	36.80	36.90	36.90	37.07	36.93	36.76	36.68	36.48	36.50	36.76
70. A. L. L.													
Dec. 20-21, 1904	36.52	36.75	36.94	36.97	36.94	36.91	36.79	37.01	36.98	36.78	36.56	36.33	36.79
Dec. 21-22, 1904	36.38	36.78	36.99	37.10	37.20	37.39	[3]37.86	37.52	37.27	36.94	36.84	36.82	37.09
Dec. 22-23, 1904	[4]37.20	37.09	37.38	37.89	38.39	38.67	38.59	38.71	39.14	38.90	38.44	38.20	38.22
Average per day	36.70	36.87	37.10	37.32	37.51	37.66	37.75	37.75	37.80	37.54	37.28	37.12	37.37
71. S. A. B.													
Jan. 7-8, 1905	36.57	37.14	36.94	37.02	36.89	36.73	36.93	36.53	35.78	36.12	36.14	36.53	36.61
Jan. 8-9, 1905	36.92	37.06	....	....	....	....	...	....	....	....	....	....	36.99
Jan. 10-11, 1905	....	....	....	....	....	....	[1]36.22	....	....	....	....	....	.....
Average per day	36.75	37.10	36.94	37.02	36.89	36.73	36.93	36.53	35.78	36.12	36.14	36.53	36.62
72. S. A. B.													
Jan. 11-12, 1905	[5]36.69	....	....	....	....	....	....	....	....	....	....	....	.....
73. S. A. B.													
Jan. 30-31, 1905	....	36.70	36.69	36.73	36.71	36.72	36.70	36.22	36.19	....	....	....	36.58
74.[6] S. A. B.	....	....	....	....	....	....	....	....	....	....	....	....	.....
75. S. A. B.													
Mar. 4-5, 1905	....	[7]36.67	36.74	36.90	36.66	36.58	36.65	36.53	36.41	[8]35.95	36.00	36.45	36.50
Mar. 5-6, 1905	36.76	[9]36.65	36.63	36.65	36.67	36.62	36.74	36.58	35.89	35.76	36.02	36.50	36.46
Mar. 6-7, 1905	36.87	....	36.83	36.72	36.75	36.74	36.84	36.59	36.07	35.60	35.99	36.28	36.48
Mar. 7-8, 1905	36.36	36.70	....	....	36.84	36.77	....	....	....	....	....	....	36.67
Mar. 8-9, 1905	....	....	....	....	....	....	....	....	....	....	....	....	.....
Mar. 9-10, 1905	....	....	....	....	....	....	....	[10]36.27	35.83	35.79	35.61	35.84	35.87
Mar. 10-11, 1905	36.46	36.73	36.85	36.72	....	....	....	....	....	....	....	....	36.69
Average per day	36.61	36.69	36.76	36.75	36.73	36.68	36.74	36.49	36.05	35.78	35.91	36.27	36.45
76. S. A. B.													
Mar. 11-12, 1905	....	....	....	....	....	....	....	[11]36.88	36.87	36.58	36.68	36.72	36.75
Mar. 12-13, 1905	36.83	37.37	37.26	37.32	37.56	37.50	37.27	37.35	36.93	36.18	36.39	36.48	37.04
Mar. 13-14, 1905	36.69	....	....	....	....	....	....	....	....	....	....	...	36.69
Average per day	36.76	37.37	37.26	37.32	37.56	37.50	37.27	37.12	36.90	36.38	36.54	36.60	37.05
77. S. A. B.													
Apr. 8-9, 1905	....	36.34	36.38	36.29	36.37	36.35	36.31	36.07	35.71	35.53	35.76	36.16	36.12
Apr. 9-10, 1905	36.45	36.23	35.92	36.19	36.05	36.31	....	....	....	....	....	....	36.19
Apr. 10-11, 1905	....	....	....	....	....	....	[12]36.44	[1]36.44	[1]36.44	....	....	....	[1]36.44
Apr. 11-12, 1905	[13]37.00	....	[1]36.89	[1]36.78	....	[14]36.78	....	....	....	....	....	....	[1]36.86
Average per day	36.45	36.29	36.15	36.24	36.21	36.33	36.31	36.07	35.71	35.53	35.76	36.16	36.10
S. A. B. average of experiments	36.63	36.69	36.62	36.65	36.62	36.60	36.70	36.40	35.98	35.79	35.92	36.29	36.41

TABLE 190.—*Body temperature by rectal thermometer*—Continued.

Experiment number, subject, and date.	7 a.m.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	7 p.m.	9 p.m.	11 p.m.	1 a.m.	3 a.m.	5 a.m.	Average.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
79. H. E. S.													
Oct. 13-14, 1905.......	36.55	36.67	36.79	37.11	36.90	37.33	37.25	37.10	37.08	37.13	36.85	37.08	36.99
Oct. 14-15, 1905.......	37.17	36.95	36.92	37.13	37.26	37.28	37.46	37.53	37.11	37.30	37.24	36.90	37.19
Average per day..	36.86	36.81	36.86	37.12	37.08	37.31	37.36	37.32	37.10	37.22	37.05	36.99	37.09
80. C. R. Y.													
Oct. 27-28, 1905.......	36.86	37.03	36.98	36.78	36.83	37.00	36.95	36.93	37.00	37.02	37.03	37.16	36.96
Oct. 28-29, 1905.......	37.31	37.28	37.17	37.18	37.33	37.58	37.65	37.40	37.46	37.74	37.54	37.56	37.43
Average per day..	37.09	37.16	37.08	36.98	37.08	37.29	37.30	37.17	37.23	37.38	37.29	37.36	37.20
81. A. H. M.													
Nov. 21-22, 1905.......	36.39	36.59	36.18	35.97	36.80	36.45	36.60	36.29	36.02	36.02	36.14	36.27	36.31
Nov. 22-23, 1905.......	36.70	36.70	36.65	36.53	36.76	36.90	37.18	36.64	36.82	36.81	36.82	36.78	36.77
Average per day..	36.55	36.65	36.42	36.25	36.78	36.68	36.89	36.47	36.42	36.42	36.48	36.53	36.55
82. H. C. K.													
Nov. 24-25, 1905.......	[15]37.20	37.30	....	[16]36.91	36.94	36.69	36.80	36.88	36.68	36.41	36.49	36.70	36.82
Nov. 25-26, 1905.......	36.96	37.02	36.81	37.06	37.03	36.94	37.04	37.36	37.00	36.65	36.92	37.16	37.00
Average per day..	37.08	37.16	36.81	36.99	36.99	36.82	36.92	37.12	36.84	36.53	36.71	36.93	36.91
83. H. R. D.													
Dec. 5-6, 1905.........	36.58	36.83	36.99	36.71	36.46	36.50	36.20	36.51	36.33	36.37	36.31	36.49	36.52
Dec. 6-7, 1905.........	36.92	36.86	36.65	36.81	36.71	36.93	36.64	36.51	36.19	36.35	36.19	36.43	36.60
Average per day..	36.75	36.85	36.82	36.76	36.59	36.72	36.42	36.51	36.26	36.36	36.25	36.46	36.56
85. N. M. P.													
Dec. 9-10, 1905	36.82	36.65	36.57	36.45	36.50	36.93	36.87	36.84	36.47	36.20	36.13	36.45	36.53
Dec. 10-11, 1905.......	36.80	....	[17]36.61	36.74	36.71	37.00	37.22	37.32	36.96	37.00	37.00	37.17	36.96
Average per day..	36.56	36.65	36.59	36.60	36.61	36.97	37.05	37.08	36.72	36.60	36.57	36.81	36.73
89. D. W.													
Jan. 10-11, 1906.......	....	36.33	35.87	35.88	36.41	36.18	36.45	36.33	36.27	35.99	35.77	35.96	36.13
Jan. 11-12, 1906.......	35.99	36.41	36.16	36.13	36.45	36.10	36.37	36.19	36.09	35.85	35.66	[18]35.62	36.09
Average per day..	35.99	36.37	36.02	36.01	36.43	36.14	36.41	36.26	36.18	35.92	35.72	35.79	36.10
Average of all fasting experiments..	36.70	36.76	36.67	36.70	36.77	36.79	36.88	36.74	36.49	36.43	36.40	36.56	36.66
Average of all food experiments	36.72	37.00	37.14	37.32	37.52	37.62	37.63	37.49	37.44	37.08	36.98	36.91	37.24

[1] Reading by clinical thermometer in the mouth. Not included in average.
[2] Record at 7^h 30^m a. m.
[3] Record at 7^h 12^m p. m.
[4] Record at 7^h 15^m a. m.
[5] Record with clinical thermometer 97°.2 F. in the mouth = 36.22 C + .47 = 36.69 by rectal.
[6] The only obtainable records for experiment 74 were those taken in the mouth with the clinical thermometer at 5 p. m. each day of the experiment. These were respectively as follows: February 2-3, '05, 36.56; February 3-4, '05, 36.56; February 4-5, 37.00.
[7] Record at 9^h 16^m a. m.
[8] Record at 1^h 12^m a. m.
[9] Record at 9^h 20^m a. m.
[10] Record at 9^h 24^m p. m.
[11] Record at 9^h 36^m p. m.
[12] Record at 6^h 30^m and 7^h 30^m p. m., with clinical thermometer in the mouth. Not included in average.
[13] Record at 8 a. m., with clinical thermometer in the mouth. Not included in average.
[14] Record at 5^h 25^m p. m., with clinical thermometer in the mouth. Not included in average.
[15] Record at 7^h 30^m a. m.
[16] Record at 1^h 44^m p. m.
[17] Record at 11^h 12^m a. m.
[18] Record at 5^h 28^m a. m.

Jacques, and Luciani (4) and Daiber [19] on Succi, but contrary to the conclusion drawn by Hoover & Sollman (8), Senator & Mueller (7) studying Breithaupt, Jurgensen, and Benedict & Snell.[20]

Upon the ingestion of food after fasting, the body temperature tends to rise. This rise is evident in all the experiments with food here reported, but is particularly noticeable in experiment No. 70, where the rise is continuous for the three days of the experiment.

It is obvious, however, that the average temperature for the third day (38.22° C.) indicates a febrile condition and hence the temperature observation for this day can not be considered normal. In experiment No. 76, the average temperatures are likewise slightly above those of experiment No. 75, although it is evident that the defective method of averaging in both series of experiments might readily account for this difference.

The observations given in table 190 indicate that during short fasts no noticeable disturbances between thermogenesis and thermolysis can be observed. They are furthermore of specific value in furnishing data for computing the total heat production according to the formula discussed on page 49.

PULSE RATE.

As an index of the variations in the degree of muscular activity the pulse rate is of great value. Even in experiments where the external muscular activity is reduced to a minimum the pulse rate may be of greatest service in furnishing a clue to the degree of internal muscular activity, muscular tonus, etc. The heat production, carbon dioxide elimination, and oxygen consumption vary within wide limits from experiment to experiment, and indeed from day to day of the same experiment. It therefore becomes very important to secure all possible data regarding the intensity of metabolism for the fullest understanding of the phenomena of fasting. It is for this reason probably that in some of the earlier fasting experiments on record we find more or less complete observations regarding the pulse rate.

The oldest observation on the pulse rate during fasting is that of Nicholson (1), who, without giving any exact data, states that the heart sounds of the fasting prisoner under his care became rather faint and the pulse soft and slow.

Luciani (4) took Succi's pulse twice each day. The subject was resting quietly in bed, save on one occasion when he had returned from an evening visit with friends. The pulse remained, in practically all cases, between the limits of 54 and 70 beats per minute. On the occasion referred to above the pulse had risen to 85. No decrease was noted as the fast progressed.

Senator & Mueller (7) made observations on Cetti and Breithaupt twice daily. Cetti's pulse when resting varied from 68 to 92, while Breithaupt's

[19] Loc. cit. [20] Loc. cit.

varied from 47 to 66. Other observations made on these two fasters in connection with the research showed an unusual irritability of the heart. On one occasion Cetti's pulse rose from 80 to 104 when he rose from his couch and sat up. Breithaupt showed likewise an unusual irritability of the heart while doing small amounts of muscular work. These observations are in accord with the one observation made by Luciani (4), in which the increase in pulse rate after a short run was much greater with Succi than with several well-fed assistants with the same exercise.

No increase of Cetti's pulse was observed with resumed feeding, but a marked increase occurred in the case of Breithaupt on the first day after the fast.

The subject "J. A." (9) in the Stockholm laboratory took his pulse rate every two hours while he was awake. The lowest recorded rate was 62 and the highest 92. The average rates for the five days of the fast were 70.1, 70.3, 75.6, 71.1, and 70.4.

On the 2 days with food following the fast the average pulse rate was 80.3 and 78.8, noticeably higher than during the fast.

Hoover & Sollman (8) have reported the most elaborate series of observations on the pulse rate during fasting thus far recorded. The pulse was taken every 2 hours during an 8-day fast in hypnotic sleep. The pulse was highest at the time when the subject was awakened from his sleep, when a rate of 79 was observed. The nearest approach to this maximum was found on an occasion when the subject awoke, arose from the bed, and went to a water tank and drank several cups of water. At that time the pulse rose to 72. On no other occasion did the pulse rate rise above 68, and a minimum of 36 was reached. The average pulse for the 8 days was 62, 56, 48, 46, 47, 44, 43, and 46. The authors, however, point out that the pulse rate of their subject can hardly be considered as indicative of the normal since a low rate was maintained by command of the hypnotist.

Paton & Stockman (3) state that the pulse of their subject Jacques averaged from 50 to 60 beats per minute. No data regarding the variations in the average rate as the fast progressed are given.

In the first experiments made in this laboratory, the pulse rates were taken by the subjects themselves. The number of beats was counted for 2 minutes, and the average accepted as the true count. In connection with the statistics of each experiment in which the pulse was counted, records of pulse rate as taken by the subject are given. In the later experiments, the pulse rates were obtained by means of the Fitz pneumograph, and recorded by an assistant outside the respiration chamber. By this means it was possible to secure data regarding the pulse at any time of the day or night.

Marked variations in the pulse rate during different fasting days may be noted in many of the experiments. With the subject B. F. D. in experiment No. 59, the pulse rate rose gradually throughout the 3 days of the fast. In

experiment No. 68, no records of the pulse were made. But two records per day were made in experiment No. 69, and these showed general uniformity of the pulse rate from day to day, although the rate was somewhat higher on the last day than on the first. In the food experiment No. 70, immediately following fasting experiment No. 69, only two observations were made, both on the second day. The two records show an increase of about 25 beats per minute over those of experiment No. 69. The pulse rates were taken more frequently in the series of experiments with S. A. B. than in Nos. 69 and 70. In experiment No. 71, the rate steadily diminished during the four days of the fast. During the following day (experiment No. 72) food was ingested and there was a noticeable increase over the rate of the previous day.

In experiment No. 73 the pulse rate continually decreased on each of the 5 days of the fast. After the ingestion of food (experiment No. 74) the pulse rate increased materially on the first day, fell off slightly on the second, and on the third day regained the rate of the first.

In the 7-day experiment (No. 75) the pulse increased on the second day, but continually diminished on the succeeding 6 days of the experiment. After the ingestion of food (experiment No. 76) the pulse increased materially and was highest on the third day. Contrary to previous experience with this subject, in experiment No. 77, the pulse rate steadily increased for the 4 days of the fast, being highest on the last day.

In the series of 2-day experiments with different subjects, in all except experiment No. 89 the pulse rate increased on the second day. The rate during this last experiment remained about the same on both days. The pulse rate was usually lower during the night than during the day. Excepting the observations during the day itself, and comparing only those during the night it is seen that the pulse rate steadily increased during the 3 nights[a] of the experiments. In a few instances the records for pulse rate are defective during the preliminary nights and hence these can not be compared. But the increase of pulse on the 3 nights is strikingly evident in experiments Nos. 80, 82, 83, and 85, though it remained practically the same on all 3 nights of experiment No. 89.

An examination of the records for each experiment shows marked, and frequently, sudden changes in the pulse rate. In the large majority of instances the sudden increases in pulse can be accounted for by some body movement immediately preceding them, such as going to the food aperture, taking the strength tests, or changing from the reclining to the sitting or standing positions. In a number of instances, however, the marked fluctuations are not so readily explainable, and it seems not at all impossible that we have

[a] It will be remembered that the subject entered the chamber on the evening before the experiment proper began. Hence there are 3 nights and 2 days in each experiment.

here some examples of that increasing irritability of the heart observed in Succi (4) and Cetti (7) during their longer fasts. In all cases sudden changes in muscular activity, even though slight, noticeably affected the rate.

It should be noted that there was an increase in the pulse rate in all experiments in which food was ingested.

The relation between pulse rate and internal muscular work is more fully discussed in a succeeding paragraph,[a] where it is pointed out that the pulse rate is a remarkably good index of the degree of internal muscular activity. This is especially true when comparing different days of the same experiment with the same subject. It still remains a fact, however, that some subjects, notably A. H. M. (experiment No. 81), have an unusually low pulse rate, while others, as for example, S. A. B. (experiment No. 77), have a very much higher pulse, although it should be borne in mind that all the subjects were living under conditions assuring approximately the same muscular activity.

The study of the pulse rate, especially with the Fitz pneumograph, shows marked variations when the sleeping and waking hours are compared. But as this study of the pulse rate was only secondary to the securing of the heat measurements and of chemical data, the records are not sufficiently complete to permit careful consideration of the fluctuations in pulse rate from hour to hour and day to day. In subsequent experiments it is hoped that observations may be taken at sufficiently frequent intervals to show the relationship between the pulse rate, respiration rate, and body temperature, and thus permit of a strict comparison of the three factors.

An examination of the changes in the pulse rate as the experiment progresses shows that in the longer experiments, especially those with S. A. B., the pulse rate almost invariably decreased as the fast progressed. In the majority of the short experiments on the contrary, the pulse rate was greatest on the second day of the experiment. From the observations during the 3 nights the deduction may be made that there was a marked tendency for the rate to increase from day to day.

The pulse rates, then, are of specific value in this discussion only as indicating the varying degrees of muscular activity on the different days of the same experiment.

There was no opportunity to study the character of the pulse in the experiments made in this laboratory other than the occasional observations of the attending physician.

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[a] See p. 487.

RATE OF RESPIRATION.

The well-known effect of muscular work in increasing the rate of respiration makes records of this factor of importance in fasting experiments as a further index to the degree of internal muscular work. In several of the earlier fasts the respiration rate was observed.

Luciani (4) found with Succi a respiration rate of from 15 to 25 per minute. The average rate for the last week of the fast was 18 per minute.

In connection with the numerous experiments on Cetti and Breithaupt to determine the respiratory exchange, Lehmann & Zuntz (7) had occasion to record the rate of respiration. It should be said, however, that the subject was in all cases breathing through the mouthpiece of the Zuntz-Geppert respiration apparatus, and hence the rate may not have been normal. The average rate per minute for Cetti observed during the respiration experiments on the ten fasting days was 13.1, 14.1, 13.3, 14.6, 15.4, 16.2, 17.3, 17.6, 16.2, 15.7. On the second food day the average rate was 13.05 per minute. Fifteen days after the end of the fast the average rate was 12.1 per minute.

Observations were made with Breithaupt during both work and rest. The data were obtained as with Cetti during the progress of a respiration experiment with the Zuntz-Geppert respiration apparatus. The rates of respiration when at rest for the 6 days of the fast were: 19.2, 19.0, 20.4, 22.8, 26.3, 22.2 per minute, respectively. The average for the 2 days with food before the fast was 17.9 per minute, for the fasting period 21.5 per minute, and for the 2 days with food following the fast 23.6 per minute. Similar fluctuations were observed in the respiration rate during muscular work.

Paton and Stockman (3) state that during his 30-day fast Jacques's respiration rate varied from 23 to 30 per minute.

In all the experiments cited above, the respiration rate was recorded only during the waking hours. In the 8-day experiment with Sohn, Hoover & Sollman (8) recorded the respiration every hour. The average rate per minute for each day was found to be 18, 26, 20, 19, 19, 18, 17, 20, respectively. The lowest rate was 13, the highest 45 per minute. In general it was lowest during the night, although the subject was in a hypnotic sleep during the whole time of the study.

For all the Middletown experiments prior to No. 79, no data are available regarding the respiration rate. Several futile attempts were made to secure respiration rates from time to time, but it was not until the Fitz pneumograph was used that any satisfactory data could be obtained.

In experiment No. 79 the average number of respirations per minute during the preliminary night was 12. During the first day, from 7 a. m. to 11 p. m., while the subject was awake the rate was not far from 18. This high rate continued throughout the night and the next forenoon, increasing during the second day and decreasing only very slightly during the last night. On the

whole, then, there was a marked tendency for the respiration rate to increase as the experiment continued. The usual rate during the preliminary night of experiment No. 80 was 14 per minute rising somewhat (17) in the forenoon of the next day. In the afternoon the respiration was irregular (12 to 20) and during the night of October 27-28 it was noticeably higher than during the preceding night.

On the second day of the experiment the rate was slightly higher than on the first day, while on the last night the rate was practically the same as during the preceding night. The respiration rate therefore showed a distinct tendency to increase as the fast progressed.

In experiment No. 81 the respiration rate during the preliminary night was about 13. On awaking it increased to 17, but did not materially quicken during the day. While the subject was asleep during the day the rate was even less than that of the night. On the second night in the chamber (first night of the experiment proper) the rate was about 14 per minute. It was perceptibly higher on the whole throughout the second day and higher also during the last night. Here also there was a tendency for the rate to increase as the experiment progressed.

The respiration rate on the first preliminary night of experiment No. 83 was 17 per minute. During the day it increased to an average of about 20, falling off in the evening and remaining at about 16 to 19 during the night. On the second day of the experiment proper the average respiration rate was about 20, falling off somewhat during the evening, although rising again during the last 2 hours of the experiment to 20. There was therefore a slight tendency for the respiration rate to increase on the second day of the experiment, and there was a noticeable rise in the morning just before awaking.

In experiment No. 85 the respiration rate during the last part of the first night averaged 12. It remained about the same during the next day, but increased slightly in the latter part of the afternoon. During the entire remainder of the experiment the respiration rate remained singularly constant and the differences usually observed between night and day almost disappeared.

In experiment No. 89 the rate during the preliminary night was 16. During the following day it rose to 19, falling off in the evening to 16. During the second day the rate was unusually low for this subject during the forenoon, but rose to 21 at 2 o'clock, and during the 2 hours, from $6^h\ 30^m$ p. m. to $8^h\ 30^m$ p. m., remained at about 21 or 22. During the last night the rate remained practically uniform at 16 per minute.

While recorded with considerable frequency and hence of great value as supplementing the data furnished by the pulse rate for estimating the amount of internal muscular work, nevertheless the respiration rate was not studied with sufficient accuracy to enable special conclusions to be drawn from it.

It is further of interest to compare the ratios between the respiration rate and pulse rate in the series of 2-day fasting experiments. While with normal individuals the pulse rate is usually 4.5 times that of the respiration, here very wide variations in this ratio occur from day to day and indeed from hour to hour. Inspection of the data confirms the belief that at least during the first 2 days of fast the pulse rate is much more liable to fluctuations than the respiration rate.

BLOOD.

In many of the earlier fasting experiments, both with animals and with men, examinations of the blood, chemical and microscopical, were included in the routine of the investigation. Unfortunately almost all of the chemical work, when viewed from the standpoint of the present knowledge of the chemistry of the blood, is extremely unsatisfactory, and it is greatly to be regretted that the microscopical examination of the blood was not carried out in all cases by methods that are free from criticism. Although microscopic examination is a phase of investigation distinctly outside the sphere of the ordinary chemical laboratory, it was possible in some of the experiments here reported to make such examinations of the blood, although with by no means the completeness that could be desired. Such information as was obtained is accordingly here presented and the question of the influence of inanition upon the composition of the blood discussed.

Luciani, in 1890, made an examination of the blood of Succi every third day during the 30-day fast at Florence. The erythrocytes and leucocytes were counted and the relative amount of hemoglobin determined. The results are expressed in the form of a curve.[a]

The erythrocytes showed fluctuations during the fast, with a tendency for the number per cubic millimeter to increase as the fast progressed. Although convinced of the relative increase in the number of erythrocytes, Luciani contends that there is no evidence that the absolute number in the blood of the body is increased. These fluctuations are explained by Luciani as the result of changes in the water content of the blood.

The results of the hemoglobin tests showed a loss of hemoglobin unaccompanied by a loss of erythrocytes. The leucocytes were very considerably diminished (from 14,536 on the first day of the fast to 861 on the seventh fasting day). Both Luciani and Daiber * discuss in considerable detail the relations of the blood to metabolism.

Senator & Mueller (7), in reporting the results of their examinations of the blood of Cetti and Breithaupt, note an increase in the red blood corpuscles with both subjects. In the case of Cetti it was very considerable, amounting to more than 1,000,000 per cubic millimeter. The blood of Breithaupt, on the contrary, showed only a slight increase.

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[a] Das Hungern, Leipzig (1890), Tafel I. * Loc. cit.

Observations regarding the number of the leucocytes were taken on only 3 fasting days, i. e., the fourth and ninth days of the fast with Cetti and on the last day with Breithaupt. In all instances the number was considerably less than the normal. This agrees with the observations of Luciani. The observations regarding the hemoglobin in Cetti's blood showed a continued diminution, while Breithaupt's showed a slight increase. At the end of the sixth fasting day it was one-fifth greater than on the last food day, in spite of the fact that the red blood corpuscles had not increased. Senator[a] also found a slight increase in the hemoglobin content of the blood in a case of inanition with a woman 54 years of age.

In a later examination of Succi's blood by Tauszk[b] the conclusions reached were: (1) that after a short period of diminution in the number of red blood corpuscles there is a slight increase; (2) the number of white blood corpuscles decreases as the fast progresses; (3) the number of the mononuclear corpuscles decreases; (4) the number of the eosinophiles and polynuclear cells increases and finally that the alkalescence of the blood diminishes.

The samples of the blood examined in connection with the fasting experiments reported here were taken according to the method described on page 12. It frequently happened that it was extremely difficult to get a sufficient supply of blood from the finger to enable the counts to be made of the red and white corpuscles on each day of the fast, but fortunately blood smears were always obtained which afterwards were subjected to the differential count.

The regular Thoma-Zeiss hemocytometer was used in counting the erythrocytes and leucocytes. The determinations of hemoglobin were in some instances made by the Tahlquist method. In other cases a von Fleischl hemometer was used.

The same difficulties and criticisms that pertain to blood examinations in previous fasting experiments undoubtedly to a certain extent obtain here with regard to the taking of the blood sample, the enumeration of the blood corpuscles, and the hemoglobin tests.

As is seen from a record of drinking water, there were marked differences in the amount of water taken on the different days of the experiments, although on the majority of days the samples of blood were taken at about the same hour.

In experiment No. 75 the samples for blood were taken almost invariably at 9 a. m. On the 2 days when two samples were taken, the second was taken at 3 p. m.

In experiment No. 77 the samples were taken as a rule from 3 p. m. to 4 p. m.

Although the irregularity in the amounts of drinking-water consumed and

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[a] Charité-Annalen (1887), 12, p. 327.

[b] Orvosi hetilap. Budapest (1894), p. 512; abstract in Jahresbericht f. Tierchemie von Maly (1894), 24, p. 147.

in the hours of taking the samples is to be regretted, it is important to note that in the absence of digestion and muscular activity, those physiological factors that tend most to cause variation are reduced to a minimum.

The differential counts are believed to be as accurate as it is possible to make, and we are now aware of no criticism that can properly be applied to these measurements. They apparently represent the true condition of the blood of these subjects.

The results of all the blood examinations are expressed in the form of curves given on the two figures herewith.

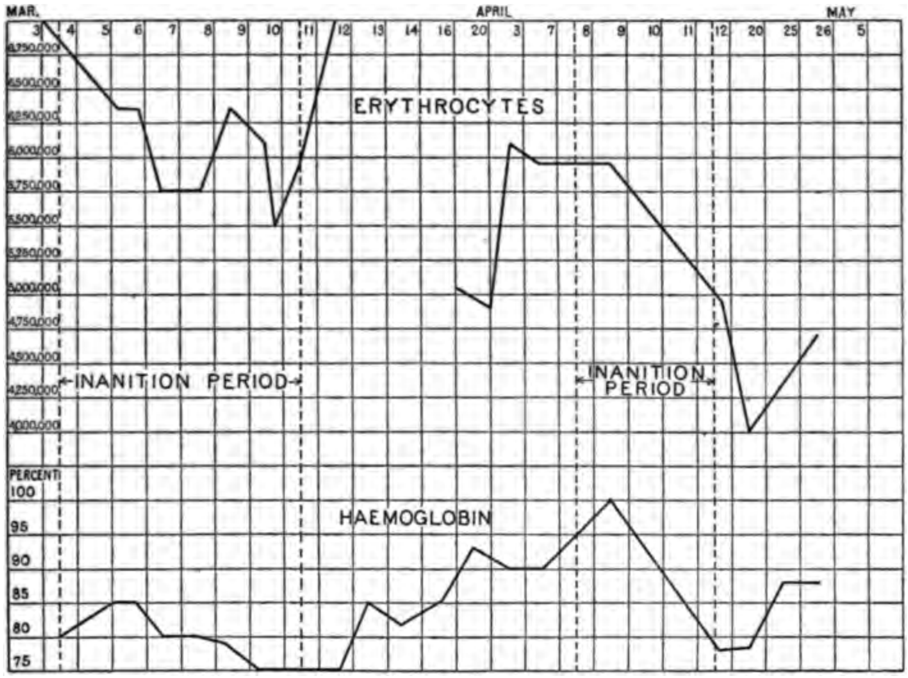

FIG. 1.

The blood examinations covered experiments Nos. 75 and 77, with a few observations on the intermediate period and the period after the last fasting day. The full interpretation of these curves is given essentially as in the formal report submitted by Dr. A. R. Diefendorf, Pathologist of the Connecticut Hospital for the Insane, Middletown, Conn.

The red blood corpuscles show only a slight diminution in number during each fasting period with a relatively rapid rise in the days immediately following the end of the fast. The same is true of the hemoglobin curve, which seems to have been more profoundly affected by the first and longer fast. The rise in the hemoglobin immediately after the end of the fast corresponds with the rise in the number of erythrocytes.

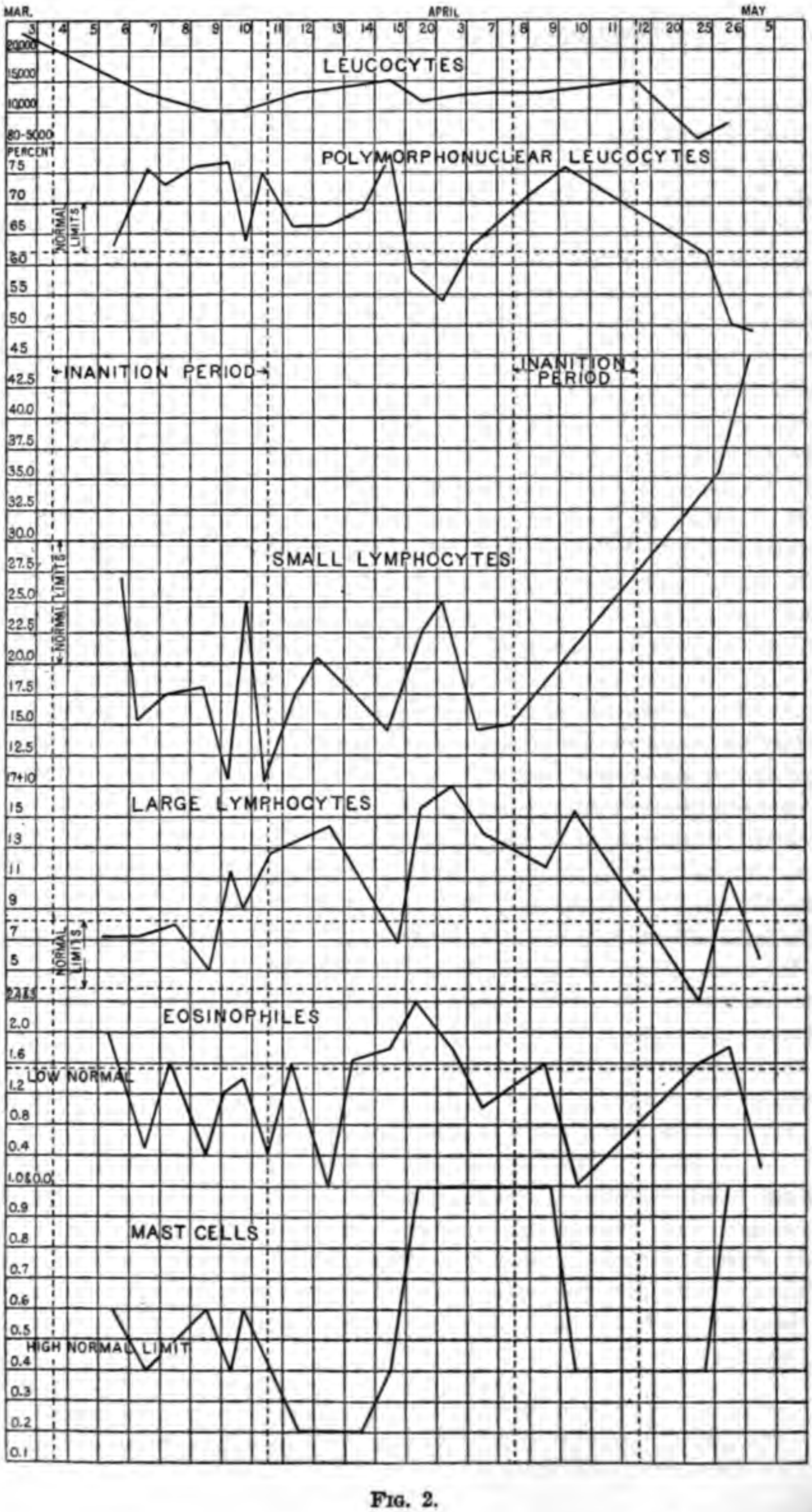
MAR.
APRIL
MAY
LEUCOCYTES
POLYMORPHONUCLEAR LEUCOCYTES
NORMAL LIMITS
INANITION PERIOD
INANITION PERIOD
SMALL LYMPHOCYTES
NORMAL LIMITS
LARGE LYMPHOCYTES
NORMAL LIMITS
EOSINOPHILES
LOW NORMAL
MAST CELLS
HIGH NORMAL LIMIT

Fig. 2.

As regards the leucocytes, it was apparent at the outset that the subject normally presented a condition usually regarded as a leucocytosis. During the long fast there was a progressive diminution until the morning of the end of the fast when there was a comparatively slight rise. The second fasting period in which the observations were made produced very little effect upon the number of the leucocytes, there being a gradual rise, amounting, however, to only 2000 leucocytes. Only in the two weeks following the end of the second fast did the number of leucocytes approach the normal.

In the differential count of the white blood corpuscles it was found that the polymorphonuclear leucocytes averaged high during the first fast, except during the second and seventh days when their number fell to low normal range, 63 and 64 per cent. During the second fast the percentage again rose above the normal level, but in neither instance did the percentage reach a distinctly pathological level. It fell below normal twice in the interval between the fasts and three times during the two weeks following the last fast.

The small lymphocytes were below normal range with the exception of two instances, namely, upon the second and seventh days during the long fast. The same average low percentage of small lymphocytes prevailed in the second fast with the exception of the last day of the fast. As regards the large lymphocytes, it was found that the percentage rose above the normal during the last two days of the first fast, and remained wholly above the normal range during the second fast.

The eosinophiles averaged low throughout the first experiment and below the normal range except on the second and fourth days. The same applies to the second fast during which the percentage rose above the low normal range upon only one day, the third.

The mast cells during the first test averaged high normal and above normal, and the same is true of the second and shorter fast

In conclusion, the most striking results of blood examinations in the continued fasts seem to be:

(*a*) The progressive average fall in the number of erythrocytes with the recuperation following.

(*b*) A corresponding diminution in the percentage of hemoglobin.

(*c*) A relative progressive fall in the percentage of leucocytes in the prolonged fast, but no remarkable effect of fasting to be seen in the relative percentages of the various types of leucocytes.

(*d*) A high percentage of polymorphonuclear leucocytes during the fasts, explained by the relative leucocytosis, which in turn explains the relatively low percentage of the small lymphocytes and the high percentage of large lymphocytes.

STRENGTH TESTS.

The popular belief that strength diminishes rapidly as a fast progresses has been based upon the innumerable personal impressions of individuals who have from time to time gone without meals and observed an apparent lack of strength. These personal impressions have been scientifically substantiated by tests with the ergograph as made by Maggiora [a] in which a rapid diminution in strength immediately follows the beginning of a fast.

The tests made by Luciani (4) on Succi in which a dynamometer was used to measure the strength of the right and left hands showed results seemingly at variance with the popular impression. Thus, on the 21st day of the fast, Succi was able to register on the dynamometer a stronger grip than when the fast began. From the 20th to the 30th day of the fast, however, his strength decreased, being less at the end than at the beginning of the fast. In discussing these results, Luciani pointed out the fact that Succi believed that he gained in strength as the fast progressed and hence probably did not exert the greatest power at the beginning of the experiment. Considering the question of the influence of inanition on the onset of fatigue, Luciani states that the fatigue curve obtained from Succi on the 29th fast day was similar to that obtained with an individual under normal conditions.

The interesting observations made by the subject of Johansson's experiments, J. A. (9), in which he noted the length of time he could suspend himself on his arm, showed a marked falling off in strength as the fast progressed. This strength was rapidly regained on the subsequent ingestion of food.

As has frequently been pointed out, tests with the dynamometer and tests such as were employed by J. A. are, however, not necessarily true indices of the actual strength but a resultant of will and strength.[b] Therefore strength tests with the hand dynamometer are of questionable value as accurate records of the strength of muscles at different periods of the fast.

In the experiments on Cetti (7) the dynamometer was not used, but the measurement of the vital capacity was taken as an index of the strength. This measurement tested the tension of the respiratory muscles. From the 5th to the 10th day there is no noticeable diminution in the vital capacity, although on taking food after the fast there was an increase of several hundred cubic centimeters above that of the fasting period.

The results with Breithaupt indicate an actual increase in the capacity of the muscles to perform work as the fast progresses.

In the series of 2-day experiments here reported, tests were made with a Tiemann hand dynamometer to secure data regarding any apparent influence of inanition on strength. In the following table the results are recorded in

[a] Arch. f. Anatomie und Physiologie, 1890, p. 227.

[b] For a more complete discussion of this point see Luciani (4), p. 56, and Lehmann & Zuntz (7), p. 184.

pounds, 1 pound being equivalent to 453.6 grams. An attempt was made to obtain data regarding the rapidity of the onset of fatigue by having the subject test the strength of the hand muscles with the dynamometer in a series of 5 to 7 tests, first with the right hand, and then with the left. In all the experiments except No. 79 and No. 80 the tests were taken in succession, finishing the set on one hand before beginning the tests on the other. At certain times only 3 and 4 consecutive observations were taken, while at other times 6 and even 7 tests were made, and hence the averages are not strictly comparable.

An examination of the data in table 191 shows that as a rule the strength decreases rapidly at the beginning of the fast and is almost immediately, in part at least, regained with the ingestion of food.

In experiment No. 89 there was a marked increase in strength on the first day of fasting, followed by a slight loss on the second day. The effect of the subsequent ingestion of food in increasing the strength is not as noticeable in this experiment as in others. This is doubtless due to the small loss observed in the fasting period.

The records were not made at sufficiently frequent intervals to draw any particular conclusions regarding the fluctuations in the strength for different periods of the day. In general, the observations accord with the conclusions of Mosso and Maggiora with the ergograph, namely, that as the fast progresses there is a noticeable falling off in the strength as measured by the hand dynamometer. After renewed ingestion of food, the strength is rapidly regained. The apparent onset of fatigue seems in general to be somewhat more rapid as the fast progresses, but the data are not sufficient to warrant any positive statements on this point.

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments.*

METABOLISM EXPERIMENT No. 79.

Date.	Hand.	Record of individual tests.	Average.	Total.
		Pounds.	*Lbs.*	*Lbs.*
Oct. 13, 9 a. m., fasting	Right	100 92 93 92 93	94	
	Left	95 85 81 80 80	84	178
Oct. 14, 9 a. m., fasting	Right	88 85 84 82 80	84	
	Left	75 70 70 70 70	71	155
Oct. 14, 8 p. m., fasting	Right	88 85 78 80 78	82	
	Left	80 70 65 60 65	68	150
Oct. 15, 7h 15m a. m., fasting	Right	95 84 80	86	
	Left	85 70 70	75	161
Oct. 16, 3 p. m., food	Right	95 93 91 90	92	
	Left	87 76 80 75	80	172

METABOLISM EXPERIMENT No. 80.

Date.	Hand.	Record of individual tests.	Average.	Total.
Oct. 26, 8h 45m a. m., food	Right	105 106 108 103 85	101	
	Left	100 106 86 84 94	94	195
7 40 p. m., food	Right	115 111 108 96 107	107	
	Left	95 94 85 84 94	90	197
Oct. 27, 9h 00m a. m., fasting	Right	94 90 94 95	93	
	Left	90 84 90 84	87	180
4 07 p. m., fasting	Right	106 105 99 95	101	
	Left	95 89 95 90	92	193
11 00 p. m., fasting	Right	94 90 93	92	
	Left	88 82 81	84	176
Oct. 28, 9h 00m a. m., fasting	Right	90 90 99 99	95	
	Left	86 81 88 81	84	179
5 00 p. m., fasting	Right	88 95 92 88	91	
	Left	84 80 74 84	81	172
11 00 p. m., fasting	Right	92 90 95 95	93	
	Left	88 86 87 78	85	178
Oct. 29, 7h 00m a. m., fasting	Right	102 97 101 98	100	
	Left	93 85 86 80	86	186
9 15 a. m., food	Right	105 107 110 109 108	108	
	Left	95 93 95 95 89	93	201
11 30 a. m., food	Right	107 117 110 110 109	111	
	Left	95 96 95 92 105	97	208
2 10 p. m., food	Right	125 128 121 110 116	120	
	Left	105 108 120 103 100	107	227

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments*—Continued.

Date.	Hand.	Record of individual tests.								Aver-age.	Total.
METABOLISM EXPERIMENT No. 80—(Cont'd.)											
		Pounds.								*Lbs.*	*Lbs.*
Oct. 29, 7h 10m p. m., food.......	Right.	109	98	95	95	90	..	..	..	97	
	Left..	90	80	90	90	80	..	..	..	86	183
Oct. 30, 8h 45m a. m., food.......	Right.	104	101	119	106	101	..	..	..	106	
	Left..	89	88	100	89	95	..	..	..	92	198
METABOLISM EXPERIMENT No. 81.											
Nov. 20, 8h 30m a. m., food.......	Right.	82	83	79	81	84	82	80	..	82	
	Left..	81	79	84	86	81	83	83	..	82	164
12 10 p. m., food.......	Right.	86	83	75	67	83	86	86	84	81	
	Left..	81	82	78	75	79	84	80	81	80	161
3 40 p. m., food.......	Right.	82	82	79	80	79	80	80	81	80	
	Left..	78	69	78	71	71	73	79	78	75	155
7 40 p. m., food.......	Right.	84	76	73	75	71	78	70	72	75	
	Left..	71	81	73	78	74	69	71	71	75	150
Nov. 21, 9h 00m a. m., fasting.....	Right.	85	84	80	68	81	80	82	..	80	
	Left..	82	82	80	79	75	65	82	..	78	158
3 00 p. m., fasting.....	Right.	83	81	81	80	75	75	..	..	79	
	Left..	83	82	79	73	80	84	..	..	80	159
9 00 p. m., fasting.....	Right.	71	78	78	70	74	63	78	..	73	
	Left..	75	78	86	79	81	85	81	..	81	154
Nov. 22, 9h 00m a. m., fasting.....	Right.	75	76	77	81	78	76	..	..	77	
	Left..	80	78	75	72	84	74	..	..	77	154
7 00 p. m., fasting.....	Right.	83	81	75	75	79	85	80	..	80	
	Left..	78	83	84	80	78	78	80	..	80	160
Nov. 23, 7h 00m a. m., fasting.....	Right.	80	79	80	78	82	82	75	..	79	
	Left..	82	81	80	80	82	82	83	..	81	160
9 45 a. m., food.......	Right.	84	86	77	83	82	78	..	..	81	
	Left..	75	86	85	84	86	88	..	..	84	165
1 45 p. m., food.......	Right.	86	84	82	82	86	83	74	..	82	
	Left..	75	81	80	78	80	73	80	..	78	160
Nov. 24, 10h 40m a. m., food.......	Right.	87	86	87	86	87	84	90	..	87	
	Left..	87	83	82	85	81	85	87	..	84	171

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments*—Continued.

METABOLISM EXPERIMENT No. 82.

Date.	Hand.	Record of individual tests.								Average.	Total.
		Pounds.								*Lbs.*	*Lbs.*
Nov. 23, 8^h 15^m a. m., food.......	Right.	100	90	90	84	73	82	74	70	83	
	Left..	88	88	81	88	75	73	78	68	80	163
Nov. 24, 9^h 00^m a. m., fasting....	Right.	100	84	74	80	80	70	72	..	80	
	Left..	99	80	99	80	76	82	80	..	85	165
3 00 p. m., fasting....	Right.	95	79	65	79	79	82	75	..	79	
	Left..	82	88	80	90	85	84	80	..	84	163
10 00 p. m., fasting....	Right.	84	75	85	94	71	74	85	..	81	
	Left..	100	88	70	70	82	71	70	..	79	160
Nov. 25, 11^h 00^m a. m., fasting....	Right.	88	82	66	62	75	68	65	79	73	
	Left..	75	70	61	54	53	65	56	..	62	135
3 40 p. m., fasting....	Right.	86	69	78	74	68	70	71	..	74	
	Left..	75	71	69	60	67	64	72	..	68	142
9 30 p. m., fasting....	Right.	70	70	62	63	52	55	55	..	61	
	Left..	69	66	55	60	54	55	55	..	59	120
Nov. 26, 7^h 00^m a. m., fasting....	Right.	74	65	65	58	52	65	66	..	64	
	Left..	87	82	78	65	60	70	69	..	73	137
9 30 a. m., food.......	Right.	84	76	70	68	66	56	73	..	70	
	Left..	85	70	72	64	63	56	55	..	66	136
12 30 p. m., food.......	Right.	90	80	85	76	85	84	..	..	83	
	Left..	91	80	71	70	73	80	..	..	78	161
3 10 p. m., food.......	Right.	90	80	79	71	82	80	..	..	80	
	Left..	89	77	75	73	70	74	..	..	76	156
6 40 p. m., food.......	Right.	89	74	62	65	80	81	..	..	75	
	Left..	80	70	71	80	83	86	..	..	78	153
Nov. 27, 7^h 10^m a. m., food.......	Right.	80	65	57	74	80	77	..	..	72	
	Left..	62	61	60	75	70	70	..	..	66	138
8 16 a. m., food.......	Right.	88	81	80	88	84	86	76	78	83	
	Left..	90	83	73	71	76	76	76	64	76	159
4 50 p. m., food.......	Right.	86	71	81	85	85	70	80	89	81	
	Left..	91	81	79	78	76	74	70	..	78	159
Dec. 4, 3^h 00^m p. m., food.......	Right.	93	80	74	74	75	79	..	..	79	
	Left..	89	71	82	70	74	80	..	..	77	156

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments*—Continued.

Date.	Hand.	Record of individual tests.								Average.	Total.
METABOLISM EXPERIMENT No. 83.											
		Pounds.								*Lbs.*	*Lbs.*
Dec. 4, 10h 05m a. m., food.......	Right.	95	92	76	80	74	77	71	73	80	
	Left ..	63	53	56	51	52	54	58	56	55	135
3 15 p. m., food.......	Right.	89	81	76	81	83	80	79	71	80	
	Left ..	72	55	58	52	56	57	51	59	58	138
Dec. 5, 11h 00m a. m., fasting....	Right.	85	73	82	80	83	72	61	78	77	
	Left ..	55	59	55	50	58	56	47	43	53	130
7 00 p. m., fasting....	Right.	78	78	66	70	72	71	56	76	71	
	Left ..	56	59	52	51	46	48	48	43	50	121
Dec. 6, 11h 00m a. m., fasting....	Right.	82	81	73	72	75	70	68	58	72	
	Left ..	53	44	53	51	50	40	51	49	49	121
7 00 p. m., fasting....	Right.	71	68	64	65	55	61	60	56	63	
	Left ..	55	62	53	53	47	48	51	41	51	114
Dec. 7, 9h 00m a. m., food.......	Right.	83	72	61	64	66	65	68	71	69	
	Left ..	61	54	50	53	53	49	51	53	53	122
7 30 p. m., food......	Right.	87	71	73	80	63	61	73	78	73	
	Left ..	58	56	52	53	54	52	49	51	53	126
Dec. 8, 7h 30m a. m., food.......	Right.	94	86	81	61	81	78	74	[1]70	78	
	Left ..	65	63	58	57	53	54	52	[1]58	58	136
10 00 a. m., food.......	Right.	85	81	68	71	65	65	72	[1]60	71	
	Left ..	67	63	53	54	53	53	57	[1]54	57	128
METABOLISM EXPERIMENT No. 85.											
Dec. 8, 9h 10m a. m., food.......	Right.	64	54	59	54	70	69	56	68	62	
	Left ..	63	61	56	63	53	53	59	56	58	120
3 20 p. m., food.......	Right.	82	76	70	68	70	59	68	67	70	
	Left ..	73	68	61	63	63	64	58	60	64	134
Dec. 9, 9h 10m a. m., fasting....	Right.	56	59	62	63	44	48	54	45	54	
	Left ..	53	48	47	40	34	46	49	50	46	100
3 40 p. m., fasting....	Right.	52	51	42	49	51	43	53	47	49	
	Left ..	48	36	42	43	42	41	36	39	41	90
9 05 p. m., fasting....	Right.	53	49	45	44	46	38	44	34	44	
	Left ..	44	48	44	48	52	48	43	36	45	89

[1] Additional records: 7.30 a. m., right, 78; left, 63. 10.00 a. m., right, 73; left, 59.

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments*—Continued.

Date.	Hand.	Record of individual tests.								Average.	Total.
METABOLISM EXPERIMENT No. 85—(Cont'd).											
		Pounds.								*Lbs.*	*Lbs.*
Dec. 10, $11^h\ 30^m$ a. m., fasting....	Right.	56	46	45	42	51	41	36	44	45	
	Left..	42	42	36	38	50	40	49	45	43	88
4 05 p. m., fasting....	Right.	63	55	53	56	41	49	51	44	52	
	Left..	43	46	41	32	47	42	46	32	41	93
9 20 p. m., fasting....	Right.	58	48	46	58	46	49	52	39	50	
	Left..	41	41	54	39	49	41	43	44	44	94
Dec. 11, $11^h\ 00^m$ a. m., food.......	Right.	58	58	53	53	61	48	51	51	54	
	Left..	51	51	43	38	51	46	48	40	46	100
10 00 p. m., food.......	Right.	58	51	51	56	49	61	58	47	54	
	Left..	58	49	47	47	41	39	54	48	48	102
Dec. 12, $3^h\ 15^m$ p. m., food.......	Right.	74	64	66	60	52	53	67	62	62	
	Left..	59	62	59	57	50	53	50	55	56	118
Dec. 13, $3^h\ 00^m$ p. m., food.......	Right.	69	59	72	66	63	56	64	52	63	
	Left..	56	63	57	59	53	60	53	56	57	120
Dec. 14, $12^h\ 10^m$ p. m., food.......	Right.	72	62	62	65	59	55	60	63	62	
	Left..	72	63	56	59	53	51	55	62	59	121
Dec. 15, $4^h\ 00^m$ p. m., food.......	Right.	78	65	72	54	68	62	68	58	66	
	Left..	60	70	75	55	58	52	62	55	61	127
METABOLISM EXPERIMENT No. 89.											
Jan. 9, $8^h\ 30^m$ a. m., food.......	Right.	126	92	81	90	88	82	85	92	92	
	Left..	84	80	81	78	88	75	75	73	79	171
12 noon, food.........	Right.	104	98	95	82	98	88	82	88	92	
	Left..	84	84	80	86	80	82	74	89	82	174
Jan. 10, $1^h\ 40^m$ p. m., fasting....	Right.	95	88	89	83	81	84	81	79	85	
	Left..	93	100	88	88	82	81	83	76	86	171
8 00 p.m., fasting....	Right.	100	105	110	105	95	100	93	86	99	
	Left..	95	73	82	91	82	71	72	72	80	179
10 00 p. m., fasting....	Right.	106	115	108	101	97	98	84	91	100	
	Left..	91	74	86	84	81	78	80	74	81	181
Jan. 11, $1^h\ 42^m$ p. m., fasting....	Right.	98	85	85	90	85	86	81	75	86	
	Left..	89	87	74	74	76	72	63	76	76	162

TABLE 191.—*Strength tests with hand dynamometer, preliminary to, during, and following metabolism experiments*—Continued.

METABOLISM EXPERIMENT No. 89—(Cont'd).

Date.	Hand.	Record of individual tests.								Average.	Total.
		Pounds.								*Lbs.*	*Lbs.*
Jan. 11, 8h 00m p. m., fasting....	Right	95	95	92	86	86	72	72	79	85	
	Left	94	91	88	71	81	81	79	88	84	169
10 00 p. m., fasting....	Right	91	91	95	95	84	91	78	79	88	
	Left	90	91	72	78	75	73	78	75	79	167
Jan. 12, 3h 00m p. m., food.......	Right	95	91	92	85	86	81	79	81	86	
	Left	93	88	88	84	81	72	74	79	82	168
8 16 p. m., food.......	Right	95	95	95	88	88	89	89	90	91	
	Left	95	99	85	80	79	82	75	82	85	176
10 20 p. m., food.......	Right	105	110	104	93	93	86	85	89	96	
	Left	90	90	83	84	83	84	74	76	83	179
Jan. 13, 2h 10m p. m., food.......	Right	94	95	88	83	79	80	86	84	86	
	Left	97	83	81	79	78	78	78	71	81	167
8 15 p. m., food.......	Right	85	86	91	92	89	81	81	84	86	
	Left	88	82	81	74	80	80	74	80	80	166
10 00 p. m., food.......	Right	99	99	91	92	90	91	89	85	92	
	Left	88	92	85	75	79	74	66	95	82	174

PHYSICIAN'S REPORT.

Many of the subjects of the fasting experiments here reported were inexperienced in experiments of this nature. To insure the use of normal, healthy persons, and to strengthen their confidence, arrangements were made with Dr. J. E. Loveland, a practicing physician, to examine each of the men before beginning the fasts. In certain of the longer experiments he was also requested to visit the laboratory each day, and to report the condition of the subjects as the fasts progressed.

The results of his observations during the progress of three of the longer fasts are recorded in the reports given herewith.

The following is my report as attending physician to S. A. B., the subject who fasted in the calorimeter from January 7-11, 1905. The observations were made by telephoning to and inspecting the subject through a double glass window, the subject being in a dimly lighted room. Such observations were limited to noting the subject's mental condition as shown by oral and written statements, the facial expression, the actions, movements, tone and strength of voice, color of skin, condition of mouth and tongue, and physical condition, including pulse rate and strength and body temperature as reported by the subject. During the 4 days of

the fast there was no perceptible change to my mind in any particular, save that a thin, white, moist coating of the tongue at the start developed in 4 days into a moderately thick, white, moist coating, and the blood pressure in the radials was lowered enough during the stay in the calorimeter to be perceived by the examining finger.

Yours respectfully,
JOHN E. LOVELAND, M. D.

The reports for experiments No. 75 and No. 77 follow:

During the fasting experiment of March 4-10, 1905, I visited your subject at practically the same hour each afternoon and endeavored to judge of his condition by observing him through the window of the calorimeter, talking to him through the telephone, reading his written reports, and observing his pulse rate and force by the examining finger introduced through the rubber curtain. As far as could be made out by my observations, the history of the subject's condition during this fasting experiment was almost entirely uneventful. On the sixth day of the fast the subject expressed himself as feeling doubtful about his condition. On all other days he was more or less buoyant. On the seventh day of the fast and the first day of food he appeared to show emaciation in the face and the color of the skin appeared slightly dusky. On the same days the subject showed a slight sordes on the gums and the tongue was slightly swollen showing indentations by his teeth. The tongue on the first day of the fast showed a moderately thick white coating, which grew thinner during the fast.

The pulse rate varied from 50 to 68 beats per minute. The rate, roughly speaking, tended to grow less as the fast progressed. On the first day with food it rose to 74.

On the fourth day of the fast the force of the pulse appeared less than on previous days. On the fifth day there was an irregularity noted—the individual beats varying in force. On the sixth and seventh days of fasting, and the first day with food, the force appeared greater than on the other 5 days. At no time did the pulse rate and force appear to approach a dangerous condition. At the end of the fast the subject was in a condition that, in my opinion, would have warranted his continuing the fast with impunity.

During the fasting experiment of April 8 to 11, 1905, the subject's mental condition, as shown by his statements, his facial expression, his carriage and actions, was one of depression and apprehension. His physical condition was apparently normal. On the first day there was a moderately thick, dirty, white coat on the tongue. This coating appeared less thick on the second day and did not change in character from that day. The pupils were moderately dilated on the fourth day. The pulse was always of good quality.

JOHN E. LOVELAND, M. D.

SUBJECTIVE IMPRESSIONS AND OBSERVATIONS REGARDING GENERAL CONDITION.

It is commonly believed that the withdrawal of food for one or two meals results in dizziness, a feeling of faintness, and, at times, in pains in and about the epigastrium. With fasting men the experiences are varied. The fast of Merlatti,[a] which was said to have continued 50 days, was characterized by

[a] Monin et Maréchal; Stefano Merlatti, Histoire d'un jeûne célèbre. Paris (Marpon et Flammarion).

extreme discomfort, pain, and sensation of coldness. During the 30-day fast of Jacques (3) the only marked discomfort noticed was a slight attack of gout which appeared on the 16th day. In the numerous fasts of Succi (4) no marked discomfort was observed. In fact during his fast at Florence his cheerfulness and apparent good health were the subject of much comment. It should be stated, however, that both Jacques and Succi took small amounts of narcotics from time to time throughout their fasts, though, as Prausnitz (5) has pointed out, this may have been as much to stimulate a popular interest in the concoctions as to dull the senses to any possible pain, except possibly during the early days of the fast. Cetti (7) experienced considerable discomfort during the first one and one-half days of his fast, but this suddenly ceased after a movement of the bowels. The condition during Breithaupt's (7) experiment was somewhat complicated by the fact that on the third day of the experiment he contracted a cold in the head which caused him discomfort with a slight temperature increase. It was the opinion of Senator and Mueller (7) that the disturbances observed in both cases were not marked enough to cause any material effect on the metabolism. The records of the subjective impressions of J. A. (9) in the experiments in the Stockholm laboratory show that on the first day of the fast he noticed no dizziness. On the second day, while his general condition was good, he observed unusual weakness following a slight muscular exertion. On the third day he was in not a little discomfort and was dizzy when climbing on a short ladder inside the respiration chamber. On the fourth day the pain in the stomach disappeared and no dizziness was noticed in the experiment on the ladder. On the fifth day the general condition was excellent, and there was no pain or discomfort in the stomach. His strength, too, was greater, although he noticed that if he arose suddenly from the bed there appeared to be black spots before the eyes.

Rosemann,[*] who fasted forty hours, records that on the first day there was no very noticeable feeling of hunger. On the second day he was hungry, especially at the regular meal hours. There was furthermore a feeling of weakness and a pain in the heart with palpitation. The effect of climbing a ladder was to cause dizziness.

In the series of 2-day experiments made by Prausnitz (5) discomfort was experienced in one or two cases, but on the whole the subjects had no pain or other disagreeable results from the fast. There was in general a feeling of weakness on the second day, although all the subjects went about their usual daily occupations. In Prausnitz's opinion the feeling of discomfort attending hunger is, in many instances, a purely psychical condition.

That the psychical condition has much to do with the feelings of discomfort during fasting is clear from observation of the notes made by the subjects of

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[*] Archiv f. die ges. Physiologie (1897), 65, p. 359.

the Middletown experiments. During a large majority of the fasts the only discomfort noticed was a slight headache or dizziness, and a number of the subjects were cheerful and contented. The attempt to read by means of the insufficient light in the chamber may well account for much of the pain in the eyes and perhaps also for the dizziness. The psychical condition of the subject S. A. B., who was distinctly of a hypochondriacal disposition, determined in a very large measure his subjective symptoms. For example, during the longest fast, 7 days in experiment No. 75, he reported himself in excellent condition and his attending physician substantiated his statement. In fact, at the conclusion of the 3-day food experiment following this fast, the subject remarked to the assistants in the laboratory that he could have fasted for three days more. On the contrary, in experiment No. 77, although the subject had endured the 7-day fast inside the calorimeter with excellent results, he was extremely apprehensive and nervous.

In the series of 2-day experiments a feeling of weakness and occasionally a sense of hunger were the only disagreeable sensations noted.

It seems, therefore, that from the experiments made in this laboratory the conclusion can properly be drawn that fasting, per se, produces no marked symptoms of pain or weakness, at least during the first days of inanition.

FECES.

The excretion of feces has commonly been considered to be the rejection of undigested food material. From more careful examination of the nature and composition of feces, however, it is seen that undigested food may form but a small portion of the total fecal mass. Among the ingredients of normal feces may be mentioned residues of digestive juices and epithelial tissue. These are conveniently termed the "metabolic products." Since under ordinary conditions these are incident to the passage of food through the body, the practice of considering feces undigested food is not without some justification. For while the metabolic products are not a part of the food passing through the alimentary tract, yet they are present in the feces as a result of the ingestion and digestion of food, and hence they may properly be considered as material expended for the digestion of food and should be taken into account in discussing digestibility or the cost of digestion.

A number of experimenters have in recent years attempted to study the formation of feces by ligaturing a loop of the intestine, analyzing the contents of the ligature and comparing the composition of this matter with that of normal feces. After the ligature was made and the wound healed the diet was resumed, and under these conditions there was a large amount of material thrown off from the intestinal wall into the ligatured section. This closely resembled fecal matter. It had a chemical composition not unlike that of feces

resulting from a flesh diet, and many analyses of so-called "fasting feces" show a similar chemical composition. Indeed, Voit, on the basis of the quantity of material thus secured by a ligature of a section of the intestine, has computed the total amount that would be found in the whole intestine. This was found to correspond with the total quantity of feces excreted during normal feeding experiments. It is a well-known fact that fasting animals while passing feces with more or less regularity, reject much smaller amounts of fecal matter than do animals which are fed.

If, therefore, the material formed in a ligatured intestine is a true index of the actual amount thrown off under normal conditions during fasting, there must be a marked subsequent absorption of such material as it passes farther along through the intestines. Hence it is not logical to conclude that because large amounts of epithelial débris are found in the ligatured intestine of a dog consuming food, proportional amounts may be formed and pass through and out of the alimentary tract during fasting.

The withdrawal of food results in a cessation of the stimuli to peristalsis and thus affects the expulsion of feces, while the total mass of fecal matter becomes diminished as a result of the absence of undigested material, the diminished flow of digestive fluids, and the decreased mass of intestinal débris resulting from the quiescence of the alimentary tract. Fasting, therefore, affects first the amount and regularity of defecation.

In considering the influence of fasting on the frequency of defecation, it is important to note that there is usually a normal amount of partially digested food in the alimentary tract at the beginning of a fast. Moreover, in many instances the subjects partake of an unusually large amount of food on the day, if not, indeed, the last meal of the day, immediately preceding the first day of the fast. As a result, this undigested and partially digested food in all probability undergoes the normal digestive processes, and gives rise to the production and flow of digestive juices, leaving according to its nature more or less unabsorbed material in the alimentary tract. Obviously, the fecal matter resulting from food thus ingested prior to the fast can not in any way be considered as fasting feces. The influence of the fecal matter thus formed on the regularity of defecation during fasting naturally varies with the amount and character of the diet before the fast, the length of time intervening between the last meal and the beginning of the fast, and the usual habits of defecation of the subject.

In the large majority of the fasts recorded in the literature, no feces were passed during the fasting period. This was the case in Schaefer's[*] observations on the fasting insane.

Nicholson's fasting prisoner (1) did not defecate until the twelfth day of the experiment, though only the first 6 days were wholly without food.

[*] Loc. cit.

During the 30-day fast reported by Paton and Stockman (3) there was no excretion of feces during the whole period of the fast except on the first day when a few pilular masses were passed.

In the 10-day fast of Cetti (7) feces were passed only once, i. e., at the end of the seventh fast day when about 175 grams were collected.

Breithaupt (7), during a 6-day fast, passed 37.5 grams of fresh feces on the first fasting day and 107 grams at the end of the third fasting day. No more feces were collected till after the period of inanition.

Landergren * does not state that feces were passed during his experiment, but notes that it was impossible to separate the fasting feces.

With the subject J. A. (9) no feces were passed between 7^h 45^m a. m. on the day before the fast and 7^h 40^m a. m. on the second day after it concluded.

Sohn, the subject of Hoover and Sollman (8), did not defecate during the 8 days of an hypnotic sleep. It should be added, however, that suggestion was used to prevent defecation.

Flora Tosca (11) during her 15-day fast defecated but once, i. e., the evening of the sixth day:—after taking a saline purgative.

Baumstark and Moler † report that no feces were passed by the fasting woman (Schenk) between the second and fourteenth days of fasting. No weights of feces are given.

Owing to long retention in the colon, fasting feces become hard, much dried and pilular, and frequently cause considerable uneasiness. Much difficulty is experienced in passing them, and at times they may cause considerable pain with slight hemorrhages. The use of an enema to remove fecal matter during inanition is quite common. This method was employed throughout the 30-day fast of Succi, reported by Luciani.

Separation of feces.—In studying the feces resulting from different diets, it is common to separate that portion of the feces belonging to one diet from that belonging to another by means of some material which will either color the feces or will mingle with them in such other manner as to enable the separation to be sharply made. For the coloring material carmine, charcoal, and lampblack have most commonly been used, while the other type of separating agent has more commonly been berry and fruit seeds, silica, and other similar insoluble materials. While with subjects undergoing experiments in which a sufficient quantity of food is given, these separating agents serve fairly well to distinguish the feces resulting from the different foods, the difficulties incident to the separation of fasting feces are much greater.

It may reasonably be questioned whether the presence of berry seeds or indeed even coarsely powdered charcoal may not result in a stimulation to

* Loc. cit.

† Zeit. f. experimentelle Pathologie und Therapie (1906), 3, p. 687.

peristalsis, if not, indeed, to a flow of digestive juices which would compare with many normal diets, and hence the fecal products are not necessarily representative of an absolute fast. The use of an insoluble material requires the separation to be made in many instances with the aid of the microscope, and it is probably true that the most reliable information regarding the nature of feces is furnished us by this instrument. In the fasting feces of Cetti, studied by Mueller, numerous tobacco fibers resulting from the large number of cigarettes consumed by this subject, were found throughout the whole mass. Knowing as we do the irritating or stimulating action of undigested cellulose in inducing peristalsis and consequent abrasion of epithelial débris, it is to be questioned whether feces which have been produced under conditions favoring the presence of cellulose material in quantities even so slight as those necessarily resulting from the small amount of cigarette tobacco involuntarily swallowed are, strictly speaking, fasting feces.

In a number of experiments the attempt has been made to separate the feces by means of high enemata. It is a well-known fact that enemata of this nature frequently mix the contents of the bowel in such a manner that an accurate separation is precluded. Furthermore, when the total possible amount of the fasting feces is taken into consideration, it is clear that any method of separation as gross as that involved in the use of enemata is without actual value.

Quantitative factors.—In spite of the difficulties of isolating fasting feces, a number of investigators have attempted to separate feces that might be ascribed to the fasting period. It is of interest to observe the quantitative relations of these necessarily imperfectly separated amounts. Obviously the sharpest separation of fasting feces would be expected in the longest experiments.

Of the prolonged fasts, that of Succi (4) in Florence furnishes the most satisfactory record of the collection of feces. During this fast feces were passed for the first time on the 13th day. An enema was used. Luciani attempted to secure a water content that would represent the normal and hence dried the feces and injection water until the mass was of a pasty consistency. In this form the feces weighed 117 grams. On the 16th day 2 grams of a pasty material were obtained as the result of an injection. On the 21st day a small quantity of glucose was given with the water used in the enema and the subject attempted to retain the water in the colon as long as possible and thus permit the absorption of the glucose. One and a half hours after the enema was taken a greenish yellow fluid with some particles of solid feces was passed. The solid material, weighed in the pasty form, was 19 grams. The last defecation during the 30-day experiment occurred on the 24th day. The feces had little form and weighed in the pasty condition but 12 grams. Thus during the 30 days the total weight of fecal matter estimated as of the

pasty consistency of normal feces was but 150 grams. It is much to be regretted that the actual amount of solid matter was not determined, but allowing the greatest possible error in the estimate of water content, the total quantity of dry matter for the whole experiment was probably somewhat less than that excreted daily by a man with an average diet.

The percentage of water in normal feces is not far from 75 to 80 per cent. Consequently it may readily be computed that during the 30-day fast, assuming that the pasty consistency secured by Luciani in the feces would correspond to feces with a water content of 75 per cent, the actual amount of solid matter would be not far from 37.5 grams or a little over 1 gram per day. Since, however, the last feces were passed on the 24th day of the fast, and consequently the fasting feces for the remaining 6 days were not included, the total amount of dry matter per day for 24 hours would be about 1.5 grams.

During the 10-day fasting experiment with Cetti (7) the feces were separated from those of the food eaten previously by means of the softer consistency and more yellowish-brown color. This separation was further confirmed by the microscope. The fasting feces were passed in two portions, the first of 27 grams, collected at the end of the 7th fasting day, and the second after the experiment ended. The dried portion of the feces amounted to 34.147 grams, or 3.4 grams per day, but the writer states that the separation was unsatisfactory.

With Breithaupt (7) 28 grams of so-called "fasting feces" were collected at the end of the third fasting day, and after the period of inanition 29 grams more were passed. The total weight of dry matter was 12.10 grams, or 2 grams per day. The separation of the fasting feces from those of the previous food was made by using currants. At the end of the fasting period a charcoal emulsion was used.

An attempt to separate fasting feces was made on the subject J. A. (9). The fasting experiment was preceded by a 2-day experiment with food. Before the first meal of the food experiment the subject had fasted 15 hours. With the first meal 30 grams of dried blueberries were eaten. The presence of the residues of the berries in feces indicated that they belonged to the food of the food day.[a] In order to separate the fasting feces from the second food period, the subject received in the first meal after the fast 0.5 gram of charcoal, which colored the corresponding feces gray. The total weight of air-dry[b] fasting feces as separated in this manner was 12 grams, or about 2.4 grams per day.

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[a] From the statements of the authors it was assumed that the berry residues would become intimately incorporated with the feces for both days. This assumption seems hardly tenable.

[b] 9.08 per cent of water.

Mueller,[a] in an experiment with a patient with œsophagus stenosis, states that after four days complete fast there were 17.4 grams of dried feces, or 4.35 grams per day. He also cites two instances of the fasting insane in which the quantities per day were 5.9 and 4.8 grams, respectively, of dried feces. Since, however, in at least two of these cases, the fasting period extended beyond the actual period of the observations, these amounts would be somewhat diminished. For example, in the first instance, the four days of fast during which the patient was under observation were actually the 5th to 8th days of complete inanition. Mueller calls especial attention to the fact that it was very difficult to separate the feces in this period. Furthermore, in the second case of the fasting insane, the six days were from the 4th to the 9th fasting days. No evidence is given as to whether feces were passed on or before the beginning of this period, or whether the subject simply came to the attention of the observer at this time.

In reporting the results of Luciani on Succi, Mueller has interpreted the weight of feces reported by Luciani, i. e., 150 grams, as the weight in the dried condition, while Luciani specifically states (4) that they were in all instances weighed in a pasty condition. On this basis the amount of dried material of feces excreted by Succi is reduced from 5 grams per day as computed by Mueller to about 1.5 grams.

In the Naples (6) fast, Succi passed feces amounting to 72 grams (23 grams dry matter) on the second day of the fast. By means of purgatives 317 grams of feces (80 grams dry matter) were obtained on the 11th day. Thus there were 103 grams of dry feces collected during the first 11 days. No more feces were passed during the rest of the 21-day fast.

The feces passed by Succi in the Vienna fast (10) weighed in the dry form 53 grams. They were collected twice during the 21-day fast. Unfortunately practically all the data regarding the feces were lost. The only observation on the defecation of Succi during the Hamburg fast is that of Brugsch (12), who states that during the last 14 days of the fast there was no defecation.

It has frequently been considered, especially in the earlier experiments, that all feces passed after the beginning of a fast were fasting feces. In considering specifically the problem of the formation of feces in fasting men, it is important to bear in mind that at the beginning of the fast the alimentary tract is more or less filled with material varying in composition from the partly digested food of the last meal remaining in the stomach or the upper part of the small intestine to the feces in the colon.

[a] In criticism of Mueller's observations on fasting feces, it should be said that the quantity per day observed in Cetti's experiment is recorded differently in two places. On p. 17 (Untersuch. an zwei hungernden Mensch. Reference (7)) the amount is given as 3.4147 grams per day, while on p. 106 of the same article the amount is given as 3.818 grams per day.

While unfortunately in most experiments no data are given regarding the character and amounts of the diet and the time and nature of the last defecation before the fast began, it must be recognized that a part at least of the feces collected in this manner during fasting must have resulted from the ingestion of food prior to the fast.

In the fasting experiments here reported, the data regarding the feces are extremely limited. The natural expulsion of feces is retarded by inanition and hence the defecation is not at all regular. It is of interest, therefore, to consider first the effect of inanition upon the regularity of defecation.

Depending upon the amount of food consumed on the day previous, the defecation of the first day of fasting may be quite as regular as on the ordinary food days. If, however, as is the case in many of the experiments here reported, the last meal on the day before the fast was small, there may be entire absence of defecation on the first day. An examination of the record of body movements in the different experiments shows that in experiments Nos. 59, 68, and 69 there were no feces passed. In experiment No. 70, 119.2 grams of feces were passed at 7h 40m p. m., December 22, 1904, i. e., 2½ days after the first meal following the fast. This unusual delay in defecation is explained in part at least by the fact that this subject even under ordinary conditions defecates very irregularly.

In experiment No. 71, with S. A. B., feces were passed on each of the first three days of fasting. The amounts were 241.5, 41.3, and 48.0 grams, respectively. In experiment No. 72 the feces were passed at 9h 45m a. m., January 11. In the 5 days of experiment No. 73 feces were passed with considerable regularity, i. e., on the first, second, and third days. The amounts passed were 71.6, 87.0, and 51.1 grams, respectively. No more were passed till the second day with food.

During the 7-day fast (experiment No. 75) feces were passed only on the first day, i. e., 9h 10m a. m., March 4, 1905. The amount was 48.4 grams. Three days of food followed, but feces did not appear till the last food day, March 13, when 28.1 grams of feces were passed at 7h 40m a. m.

In experiment No. 77, 144.4 grams were passed on the first fasting day at 7h 36m a. m. During the evening of April 9, owing to the discomfort experienced by the subject, about 35 grams of fresh feces were removed by means of an enema. No more feces were passed until 24 hours after the first food was taken, i. e., after the subject had left the respiration chamber.

In experiments in which the heat production is especially studied, it is desirable in so far as possible to maintain a constant muscular activity. It was found that frequently, especially during the earlier fasts, the subjects would, in many instances, on either the first or second day of the experiment, make ineffectual attempts to defecate. Aside from the disturbing element of the extraneous muscular exertion and exposure of the body, there was the dis-

comfort to the subject which might produce abnormal results. Consequently, during the series of 2-day experiments Nos. 79 to 89, warm water enemata were given before the experiments, which resulted in completely removing the contents of the lower bowel so that in but one instance (experiment No. 82) were feces passed during the fasting period.

The influence of the character of the diet taken by different subjects is probably considerable. For while the majority of the subjects of these experiments did not defecate after food was withheld, S. A. B., on the other hand, passed feces, in some fasting experiments at least, with considerable regularity. This subject commonly consumed rather large quantities of fresh and dried fruits, nuts, milk, eggs, and bread, as is seen by the menus given on pages 277 to 288. From the character of the feces obtained during the nitrogen metabolism experiments, it is seen that ordinarily he passed relatively large quantities of feces. This is to be expected from the nature of the diet consumed. Hence, in the fasting experiments made with this subject, it is not at all surprising that in some instances at least we find defecation more or less regular on the first days of the fast. It is difficult to explain the fact that feces were passed only once during the 7-day fast on this assumption, unless it be that on the day preceding the fast the subject did not partake of his usual amount of food.[34]

Making due allowance, then, for the bulky nature of the diet, the influence of inanition in retarding the time of defecation as observed in these experiments is in accord with the observations made in connection with the experiments on Jacques (3) and Succi (4).

In all of the experiments made in this laboratory the attempt has been made to recognize and separate any fecal matter that could properly be considered fasting feces. Having due regard for the possibility of the irritating action of solid material of any kind on the intestinal wall, lampblack has been used in all cases in attempting the separations.

With short fasting experiments such as those previously made in this laboratory and reported elsewhere,[35] the separation of feces was impossible. Indeed, even in experiments with food and with wide alterations in the nature of the diet between periods, it is a difficult matter to separate the feces from a 1 or 2-day experiment. When it is considered that if we accept Mueller's view that the total dry matter of feces during fasting is 3 grams per day, corresponding to a total weight of fresh feces of 12 grams, it is seen that the separation of fasting feces for one day is practically impossible. With the beginning of the series of experiments in which the fasts were to last more than 2 days, it was hoped that some positive evidence regarding the fasting feces could be obtained. With the single exception of fasting experiment

[34] The large nitrogen excretion on this day (p. 367) is opposed to this view.
[35] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

No. 73, during which 38.4 grams of fresh feces, weighing when air-dry 10.1 grams, were at first considered fasting feces, no definite indication of the formation of fasting feces could be seen. Indeed, during the longest fasting experiment, No. 75, which continued 7 days, it was impossible to distinguish with a reasonable degree of accuracy any fasting feces.

While it is undeniably true that the intestinal canal throws off from its walls material as regularly as does the integument, it is highly improbable that any considerable portion of the material thus thrown off enters the large colon as the material thus deposited may be reabsorbed. Probably a certain amount of the epithelial débris from the walls of the large colon normally collects there, and may be considered as fasting feces. The amount thus formed is, however, in all probability very much less than that shown by any measurements thus far recorded.

Chemical as well as microscopical examination of all feces passed during fasting experiments considerably longer than these are essential for a proper understanding of the nature of fasting feces.

URINE.

The chief end products of protein katabolism, at least those end products containing nitrogen, are eliminated in the urine, and while it is impossible to differentiate in the respiratory products between the carbon dioxide and water of protein katabolism, and that of fat and carbohydrate katabolism, a study of the compounds, especially the nitrogenous compounds in the urine, furnishes as accurate a measure of protein katabolism as is yet available. In the studies here reported, analyses of the urine were made with as great a degree of completeness as pressure of other work and the facilities in the laboratory would permit. Unfortunately the urines could not be analyzed with the completeness that characterizes the analytical scheme of Folin. Since the grosser study was more especially that of the gaseous exchange and heat transformations as affected by inanition, the determinations of potential energy in the urine were made. One difficulty which precluded the complete analysis of urine was the inability at times to secure sufficient material for samples. The determinations were invariably made in duplicate and in many instances in triplicate, hence large amounts of urine were necessary.

In interpreting the results of the urine analyses, each component of the urine is given special consideration.

VOLUME.

Complete fasting during which no water is consumed results in lowering in a marked manner the total amounts of urine voided per day. That this is true is borne out by all the experimental data available, though unfortunately the number of instances of complete inanition in which accurate observations

regarding the amounts of urine per day were made is relatively small, being confined to the few pathological cases in which the urine has been withdrawn each day by means of a catheter, and some cases with the fasting insane.

Schaefer [56] gives the amount of urine per day in 7 cases with fasting insane women and shows that in 4 cases of fasting without water the volume of urine varied from 550 to 162.5 cc. per day. In some of the cases in which water was taken the amounts of urine fell to 220 cc., while in no case did the quantity exceed 550 cc. per day.

In a case of œsophagus stenosis in a 19-year-old girl reported by Mueller [57] the total quantity of urine, when the subject fasted without water, varied on the 4 days of the observation only between 130 cc. and 170 cc. The body weight was, however, unusually small (34.5 to 33.0 kgs.).

The report of a case of partial fasting caused by carcinoma ventriculi, published by Seegen,[58] shows that the patient took but 35 cc. of fresh cow's milk per day and during 12 days she passed but 2230 cc. of urine. The quantities ranged from 125 to 240 cc. per day.

On the other hand, in an experiment made by Sadovyen on the subject "J," fasting without water, the quantity of urine voided was relatively large. On the first day it amounted to 898 cc. and on the second day to 913 cc.

With the subject of Hoover and Sollman (8), the volume of urine varied considerably. On the day prior to the fast, the volume was 1350 cc., while on the first day of the fast which was essentially without water, the volume was 570 cc.

In general, when water is taken during the fast, the volume of urine approaches more nearly that voided by people under normal conditions. Indeed, when moderate amounts of water are consumed, the volume of urine presents as a rule no noticeable abnormalities.

Cetti (7) voided in the 10 days of his fast 9433 cc. of urine. The quantities per day varied from 1310 cc. to 620 cc. With Breithaupt (7) the volume of urine per day was much larger, varying from 1706 on the third day to 957 on the sixth and last day.

Water was consumed on the 5 days of the fast with J. A. in the Stockholm laboratory (9) in the following quantities: 137, 560, 504, 965, and 650 cc. The following quantities of urine were voided, 692, 537, 579, 650, and 579 cc. respectively.

With Jacques (3) the collection of urine was more or less irregular as he did not always empty the bladder at a definite hour each day. The lowest amounts recorded for individual days were on the last 2 days of the fast,

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[56] Allgemeine Zeitschrift f. Psychiatrie (1897), 53, pp. 525-537.
[57] Zeitschrift für klinische Medicin (1889), 16, pp. 496-540.
[58] Sitzungsberichte der Mathematisch-Naturwissenschaftlichen Classe (1871), 63, Abth. II, p. 429.

in which the volumes of urine were 450 and 440 cc. respectively. At this period of the fast, the subject was taking about 900 cc. of liquid per day. It is moreover to be noted that since Jacques drank each day a part of his own urine, and as the amounts so drunk are not specified, no correction can be made to obtain the true intake of water.

Among the observations on urine the records of the volumes of urine voided by Succi are of unusual interest.

In the fast reported by Luciani (4) the volume of urine excreted by Succi remained quite constant. Only on the first day did the amount approximate normal. On the day before the experiment began the volume was nearly 1500 cc., while on the first day of the fast it had fallen to 900 cc., and on the second day to 500 cc. The lowest volume observed was 250 cc., on the 22d day of the fast. On the first 2 days he took no water, hence the urine excretion is comparable on those days to experiments on fasting without water. During the remainder of the fast Succi partook of water as desired.

TABLE 192.—*Volume of urine eliminated daily by fasting subjects.*

Day of fast.	Succi. At Florence.[1]	Succi. At Naples.	Succi. At Vienna.	J. A.	Cetti.	Breithaupt.	Landergren.[2]	J.[3]	Sohn.	Subject I.[5]	Subject II.[5]	Flora Tosca.	Kellei.[6]
	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
Last food day.	1475	810	....	1350	1150	815	1500	....	1350	1500	....	909	....
1..	900	960	1435	692	990	1408	770	2295	570	2780	1460	456	1020
2..	500	590	830	537	940	1232	546	2490	470	2820	970	614	460
3..	550	660	575	579	1080	1706	588	1593	530	1540	1080	1115	1220
4..	525	630	612	650	1310	1263	583	2613	[4] 1020	....	....	858	1540
5..	600	730	612	579	980	991	....	....		....	....	616	....
6..	550	620	563	....	945	957	....	....	410	....	....	594	....
7..	500	610	509	....	995	....	....	....	560	....	....	509	....
8..	450	425	578	....	790	....	....	....	820	....	....	775	....
9..	425	460	640	....	775	....	....	....	....	....	....	712	....
10..	400	410	450	....	620	....	....	....	....	....	....	619	....

[1] Estimated from curve given by Luciani (4).
[2] Skan. Archiv. f. Physiol. (1903), 14, p. 112.
[3] Reported by A. Sadovyen (2).
[4] Amount for 2 days.
[5] Reported by Schreiber and Waldvogel.
[6] Reported by A. Keller, Zeit. f. physiol. Chemie (1900), 29, p. 165.

In the Naples fast (21 days) reported by Ajello and Solaro (6), the volume of urine voided by Succi varied from 960 cc. on the first day to 410 cc. on the tenth and fourteenth days. The drinking-water varied in amount from 2170 cc. on the thirteenth day to 620 cc. on the twentieth day. After the first 9 days of the fast the subject took regularly about 30 grams of citrate of magnesium. On 4 days from 200 to 300 cc. of a saline water (Vichy eleventh day, Janos 12, 20, 21) were taken.

In the Vienna fast (21 days) reported by E. and O. Freund (10) the volumes of urine varied from 1435 cc. on the first day to 235 cc. on the 21st day. The records of the amount of drinking-water are not given. The volumes of urine from the 23d to the 30th day of Succi's fast at Hamburg, reported by Brugsch (12), are twice as large as those of the last 10 days of the Vienna fast. In the Hamburg fast, Succi voided 1030 cc. of urine on the 30th day, and the smallest volume recorded was 520 cc. on the 29th day. The subject drank about 750 cc. of water each day of the fast. This amount of liquid was increased on the 30th day by 300 cc. of a sweetened lemonade.

A tabular statement showing the daily volumes of urine voided by the subjects of the fasts discussed above, as well as those of a professional fasting woman (11), is given herewith in table 192.

Vozarik[a] in studying the influence of the character of the diet on the quantity of urine excreted, observed volumes excreted on single fasting days amounting to 905, 1405, 2240 cc., respectively. Since, as the author clearly points out, the character of the diet before the fasting period influenced in large measure the volume of urine excreted, and since unfortunately the nitrogen excretion was not determined, the results are of but little value in this discussion.

Not only have the exact data of the amounts of urine, and the water consumed, been recorded in the Middletown experiments, but the amounts of water in urine and the daily ratios of the water of urine to ingested water have also been obtained. The results are presented in table 193, page 355.

For convenience of discussion, and since the data above show that the volume is proportional to the drinking-water to a certain extent, the consumption of drinking-water is considered before proceeding to the particular point under discussion, i. e., the volume of urine.

RELATION OF DRINKING-WATER TO VOLUME.

The amount of drinking-water consumed by the subjects in different experiments varies greatly. In the experiments reported herewith the maximum consumption is 2763.2 grams on the third day of experiment No. 73, and the minimum 115.10 grams on the first day of experiment No. 89. Even in experiments with the same subject the variations are considerable. For example, in experiment No. 73 with S. A. B., the average amount of drinking water per day was 2124.74 grams, while in experiment No. 77, with the same subject, the average was 1405.45 grams. The maximum amount was consumed by this subject on the third day of experiment No. 73, 2763.20 grams, and the smallest amount on the last day of experiment No. 77, 962.00 grams. Experiments Nos. 68 and 69, both of which were made with another subject (A. L. L.), also show marked differences in the amount of water consumed.

[a] Archiv f. die ges. Physiologie (1906), 111, p. 526.

With regard to experiment No. 68, however, it is to be noted that it was preceded by a metabolism experiment in the respiration chamber and the records show that the quantity of water consumed during the preceding days was probably much less than that consumed on the days preceding experiment No. 69. On the average much smaller amounts of drinking-water were taken by the subjects in the series of 2-day fasts, Nos. 79 to 89.

With regard to the apparently excessive amounts of drinking-water consumed by S. A. B., it is to be noted that he was especially cautioned to consume considerable amounts of water. In some of the earlier experiments, especially those with A. L. L., an unusually high specific gravity was observed in the urine, and moreover the volume was insufficient to enable all the desired analyses to be made. It was considered also that the fast might be endured with less liability of causing discomfort if the volume of urine was kept relatively large and the specific gravity relatively low. Furthermore, it had been the custom of S. A. B. during his fasts in private to consume rather large amounts of water.

Having seen from the above statement that the amounts of drinking-water vary considerably with different subjects, it is of interest to note the amounts of urine passed and especially the water of urine. An inspection of the data on this point shows very wide fluctuations from experiment to experiment and even between the different experiments with the same individual. The lowest average weight per day of water in urine was in experiment No. 89 where there were but 545.89 grams. The largest daily elimination occurred on the second day of experiment No. 73, and amounted to 2928.23 grams.

In experiment No. 69, there was an average of nearly 300 grams less water in the urine per day than in experiment No 68 with the same subject. The average amounts of water eliminated per day in the urine of the subject S. A. B. was more nearly constant, i. e., 1767.01 grams for experiment No. 71; 2156.51 grams for experiment No. 73; 1709.08 grams for experiment No. 75; and 1818.35 grams for experiment No. 77.

The relationship between the amount of water in the urine and the amount of water ingested is of special significance. In column *e* of table 193 the ratios of the weight of the water in the urine to the weight of the ingested water are recorded.

The wide variations in the amounts of water consumed and the water of urine noted in all the experiments are clearly indicated by these ratios. The lowest recorded for any given day is 0.628 on the first day of experiment No. 82. The highest ratio observed was that on the first day of experiment No. 80, when the water in the urine was over 8 times that ingested, i. e., 8.326. It is noticeable that both extremes in these ratios are found in the data for the shorter fasting experiments. When the differences in body condition previous to a fast are taken into consideration, it is not at all surprising that there are

wide fluctuations in the amounts of urine voided, and therefore while the data for the 2-day experiments are of distinct value it is upon the results for the longer experiments that we must especially rely in discussing these ratios.

In all the experiments continued 3 days and over, the ratios are much more nearly constant. Thus, the lowest average ratio is 0.763 for the 4-day experiment No. 69, while the highest is 1.294 in the 4-day experiment No. 77. The individual days in these longer experiments exhibit differences ranging from 0.643 on the first day of experiment No. 69 to 1.492 on the third day of experiment No. 77.

Considering the long experiments with the same subject, namely, Nos. 71, 73, 75, and 77, the ratios range for the averages of the experiments from 0.941 to 1.294.

A close examination of the data shows that in general on those individual days in which the amount of drinking-water is over 1000 grams, the ratios vary from 0.659 to 1.592, and for those experiments in which the average amount of water consumed per day was over 1000 grams, the ratio varies from 0.846 to 1.294. Furthermore, when the amount of drinking-water on one day is materially larger than that on the following day, the ratio on the second day tends to increase. This is especially noticeable in the 2-day experiments.

The results of these comparisons show, therefore, that the amount of water in urine and consequently the volume of urine is largely dependent upon the amount of water consumed. The generality of this rule is, however, strikingly interfered with in certain instances, notably those in which the ratios are the highest. Thus, on the first day of experiment No. 80, while there were but 132.80 grams of water consumed, the urine contained 1105.75 grams, and on the first day of experiment No. 89, there were but 115.10 grams of water consumed and the urine contained 599.55 grams of water.

Even in those experiments in which the lowest ratios obtained, the quantities of urine voided are not unusually small for fasting experiments. Thus on the first day of experiment No. 82, when the ratio was but 0.628 there were 538.57 grams of water in the urine, although the subject had actually consumed 857.80 grams of water during the day.

The anomalies noted in this series of experiments almost invariably occur on the first day, a striking contrast to the records of Luciani. According to Luciani's table 1700 cc. of water were consumed on the 29th day of Succi's fast in Florence, while the volume of urine was but 350 cc. The retention of large amounts of water at the end of a fast has been frequently observed, and on the 10th and 13th days of Succi's fast at Naples the amounts of water consumed were 2025 and 2170 cc., accompanied by a urine excretion of but 410 and 480 cc., respectively.

In general, then, during the earlier stages of a fast, with the exception of the first day, the volume of urine is in large measure determined by the quantity

of drinking-water consumed. If the volume of ingested water is small the volume of urine may exceed it several times. When the volume of drinking-water is over 1000 cc. the volume of urine is usually not far from that of the water consumed.

REACTION.

In all of the samples of urine, whether tested by periods or for the whole day, the reaction was acid. The pressure of other work prevented an accurate determination of the degree of acidity. According to Brugsch (12), however, the acidity, at least in the later stages of a prolonged fast, remains nearly constant from day to day.

SPECIFIC GRAVITY.

Normal urines vary widely in their specific gravity, large volumes of urine being generally accompanied by a low specific gravity and small volumes by a high specific gravity. In the first three experiments here reported the specific gravity was taken with a carefully calibrated urinometer with which, however, it was practically impossible to make accurate record to the fifth significant figure. In all subsequent experiments a Westphal balance was used. For purposes of comparison it is important that the temperature of the urine be constant when the specific gravity is taken, and hence all determinations were made at 20° C. If the urine was colder than 20° it was warmed by an electric heater.

It is probably true, since the specific gravities in the experiments of earlier observers are as a rule recorded only to the third decimal, that a simple hydrometer was used. For comparing the different days of the same experiment, this method is fairly satisfactory, but it obviously renders difficult any satisfactory comparison between experiments not made in the same laboratory.

In the case of Breithaupt, the specific gravity remained very constant from day to day, the lowest being 1.0110 on the second and third days, and the highest, 1.0135 on the fifth day. Unfortunately the records of specific gravity given for Breithaupt's urine show the specific gravity not of the urine as voided but of the volume of urine to which the original 24-hour amount of urine was diluted before the specific gravity was taken. Hence the results are for purposes of comparison of little value.

The specific gravity of Succi's urine, in the fast at Naples, varied from 1.033 to 1.026, remaining for the most part very constant at about 1.028.

In Succi's Vienna fast the specific gravity, which was 1.023 and 1.020 on the first and second days, respectively, remained almost constant at 1.030 during the remainder of the fast.

Brugsch (12), in studying the urine from Succi during the fast at Hamburg, records the specific gravity. During the last days, 23d to 30th, the specific gravity varied only from 1.023 to 1.026, remaining for 5 successive days at

1.025. The volume of urine during this period varied from 530 to 600 cc. On the last day, however, the volume rose to 1030 cc., with a specific gravity of 1.026. The urine of the fasting woman Flora Tosca (11), varied in specific gravity from 1.0315 on the second fasting day to 1.023 on the last (15th) fasting day. The decrease was gradual as the fast progressed.

The specific gravities of the urine for the different days of the experiments here reported are given in column *f* of table 193. The highest observed on any day was that on the second day of experiment No. 89, i. e., 1.0338. The lowest for any day was on the second day of experiment No. 73, 1.0032. In the first case, the volume of urine was 522 cc., while in the second it was 2958 cc. On certain of the periods even lower specific gravities were observed than that in experiment No. 73. Thus, on referring to table 94, it will be found that the specific gravity of the urine for the period from 1 p. m. to 7 p. m., January 30, was 1.0024. The volume of urine during this period was 888 cc. The highest specific gravity, 1.0360, observed in any period was on the first day of experiment No. 69. The amount of urine for this period was 63.1 grams.

The urines of the subject S. A. B. are characterized by an exceedingly low specific gravity occasioned by the large volume of urine incident to the consumption of so large an amount of drinking-water. Aside from these exceptionally low records all the specific gravities observed come well within what would be termed normal limits. There is nothing like the constancy exhibited in the fasts of Succi in any of the experiments save Nos. 71 and 75.

TOTAL SOLIDS.

The volume and specific gravity are of interest only because together they afford a means of measuring the relative amounts of total solids in the urine, which latter have not often been determined directly by investigators. Since it seemed desirable to know more of the actual amount of these solids, especially during fasting, direct determinations of them were made in the experiments here reported. The determination of the total solids or water-free material was made as a rule by drying the urine in a vacuum to constant weight. Although there are unquestionably errors in this method, for purposes of relative comparison between different days of a given experiment or between different experiments, the data are of value. The largest amount of total solids recorded in any experiment is that on the second day of experiment No. 82, on which there were 54.93 grams[a] eliminated. The smallest amount recorded

[a] While the data given in column *g* of table 193 show that in experiment No. 59 there was an elimination on the third day of 57.70 grams, this is hardly to be considered as an accurate statement of the actual weight of solids for this day, since it was determined indirectly by calculation as described on p. 28. The same is true of the results on the 2 days of experiment No. 68. However, the total solids for the average both for experiment No. 59 and No. 68 were determined directly on a total composite sample of urine for each experiment.

is on the first day of experiment No. 71 with S. A. B., when less than half this amount, i. e., 25.51 grams, was eliminated. Considering the averages of the experiments, the lowest amount recorded is in experiment No. 71, 34.99 grams, and the highest amount is in experiment No. 59, 52.93. In general the average amount of total solids during the different experiments is not far from 40 grams per day.

On the individual days of the same experiment, there is usually an increase on the second day after which the amount remains fairly constant.

An inspection of the data of the different experiments with the same subject, S. A. B., shows an average daily elimination of total solids as follows: Experiment No. 71, 34.99 grams; experiment No. 73, 37.13 grams; experiment No. 75, 44.22 grams; and experiment No. 77, 51.35 grams. Leaving out the first day of each of these experiments, since as a rule it is lower than the other days, the averages become 38.15, 36.79, 45.15, and 54.42 grams respectively. Consequently, it appears that in experiments Nos. 71 and 73, the subject S. A. B. eliminated practically the same amount of total solids each day. In experiment No. 75, there was an average elimination of nearly 10 grams more, while in experiment No. 77 the average amount per day was about 10 grams greater than that during experiment No. 75.

While the average amount per day of total solids in the series of 2-day experiments is not far from 40 to 45 grams, yet individual fluctuations may be very considerable as, for example, in the 2-day experiment No. 82, in which on the first day there were 37.13 grams, and on the second, 54.93 grams.

RATIO OF THE TOTAL SOLIDS TO THE SPECIFIC GRAVITY.

Knowing the volume of urine excreted per day and having an accurate record of the specific gravity, it is possible by factors to compute in many instances the amount of total solids. This method of computation has frequently been used for the approximations of the clinician.

The various organic and inorganic substances dissolved in normal urine have widely varying physical properties and hence solutions of varying density. A solution of 100 grams of sodium chloride in a liter of water has a density at 15° of 1.073, while a solution of urea 1 to 10 has a density of but 1.028.

With ordinary conditions of diet, however, it has been found that the total solids in 1 liter of urine may be reasonably approximated by multiplying the last two figures of the specific gravity (as ordinarily expressed in three decimal places) by 2.33. Thus 650 cc. of urine of a specific gravity of 1.027 would contain total solids as follows: $27 \times 2.33 \times .650 = 40.89$. It is stated by some writers, that if the specific gravity is less than 1.018, more accurate results can be obtained by using the factor 2.0.

In normal urines, therefore, this factor is by no means constant. Since determinations were made of volume, specific gravity and total solids in the

urines from the experiments here reported the factor for urines from fasting men may be found from these data.

In any attempt to secure an accurate ratio between the amount of total solids and the specific gravity, it is important that all specific gravities should be taken at the same temperature. Each specific gravity was taken at 20° in the Middletown experiments. The volume of urine was not measured but was computed from the weight and the specific gravity. Hence, any errors that involve the determination of specific gravity would cause an error in the volume. Usually, however, it is difficult to see how any appreciable error on the volume could be made. The ratio (r) existing between the total solids and the specific gravity may be expressed by the following formula:

$$r = \frac{g}{b \times (sp.\ gr. - 1)}$$

in which (g) is the total weight of solids in volume (b) of urine.

The ratios thus computed for the different days and experiments are recorded in table 193.

The lowest average ratio is that of experiment No. 68, 2.1; the highest is that of experiment No. 73, 3.4. So far as the individual days are concerned, the lowest ratio is that of the first day of experiment No. 80, 2.2, and the highest, the second day of experiment No. 73, 4.1. In considering the values for the ratios, it must be borne in mind that in experiments Nos. 59 and 68, the total solids for individual days were apportioned by calculation. The average ratio for all of the experiments is somewhat higher than that commonly assumed for normal urines.

In experiments with the same individual, there are also marked differences. The ratio for experiment No. 69 is higher than that for experiment No. 68, which was made with the same individual some 8 months earlier. In the series of experiments with S. A. B., the average ratio for the first three is fairly constant, 3.0, 3.4, and 3.3. In the last experiment (No. 77), the average falls to 2.5.

In the longer fasts (experiments Nos. 69, 71, 73, 75, and 77) the average ratio is 2.9. Obviously during a fast, the relative amounts of organic and inorganic matter in the urine may vary considerably from those obtained when food is eaten. The amount of sodium chloride taken with the food, for example, may affect considerably the specific gravity. As has been pointed out, the specific gravity increases much more in proportion with an increase of sodium chloride than with urea. The larger the proportion of organic matter which consists in large part of urea, the lower the specific gravity with reference to a given weight of total solids and hence the higher the ratio. Thus a knowledge of the relative amounts of organic and inorganic matter in the total solids is essential to an understanding of the variations in the relationship between specific gravity and total solids during fasting.

TABLE 193.—*Relations between amounts of drinking-water, water in urine, specific gravity, and total solid matter in metabolism experiments without food.*

Experiment number.	Subject and date.	(a) Am'nt of water consumed.	(b) Volume of urine.	(c) Am'nt of urine.	(d) Water in urine.	(e) Ratio of water in urine to water consumed (c÷a).	(f) Specific gravity.	(g) Total solids	(h) Ratio of total solids to specific gravity.	Proportion of total solids. (i) Ash.	(j) Organic matter.
		Gms.	c.c.	Gms.	Gms.			Gms.		P.ct.	P.ct.
59....	B.F.D., Dec. 18, 1903...	1342.50	1517	1540.80	[1] 1494.50	1.113	1.0160	[1] 46.30	1.9	....	....
	Dec. 19, 1903...	1360.20	962	981.80	[1] 927.00	.682	1.0210	[1] 54.80	2.7	....	....
	Dec. 20, 1903...	1188.00	908	928.90	[1] 871.20	.733	1.0230	[1] 57.70	2.8	....	....
	Total 3 days.....	3890.70	3387	3451.50	3292.70	....	....	158.80	....	....	....
	Av. per day.....	1296.90	1129	1150.50	1097.57	.846	....	52.93	2.5	....	....
68....	A.L.L., Apr. 27-28, 1904	268.40	979	1001.70	[1] 956.40	3.563	1.0230	[1] 45.30	2.0	....	....
	Apr. 28-29, 1904	616.20	822	843.80	[1] 795.70	1.291	1.0265	[1] 48.10	2.2	....	....
	Total, 2 days....	884.60	1801	1845.50	1752.10	....	....	93.40	....	....	....
	Av. per day.....	442.30	901	922.75	876.05	1.981	....	46.70	2.1	....	....
69....	A.L.L., Dec. 16-17, 1904	647.03	437	451.80	415.75	.643	1.0330	36.05	2.5	18	82
	Dec. 17-18, 1904	553.60	572	590.10	545.08	.985	1.0310	45.02	2.5	14	86
	Dec. 18-19, 1904	1085.30	743	762.30	714.81	.659	1.0250	47.49	2.6	14	86
	Dec. 19-20, 1904	828.50	725	742.10	700.32	.845	1.0230	41.78	2.5	13	87
	Total, 4 days....	3114.43	2477	2546.30	2375.96	....	....	170.34	....	....	....
	Av. per day.....	778.61	619	636.58	593.99	.763	....	42.59	2.5	15	85
71....	S.A.B., Jan. 7-8, 1905	1204.40	1149	1159.50	1133.99	.942	1.0089	25.51	2.5	30	70
	Jan. 8-9, 1905	1973.20	2009	2021.10	1984.11	1.006	1.0058	36.99	3.2	16	84
	Jan. 9-10, 1905	2312.90	2529	2541.60	2500.68	1.081	1.0048	40.92	3.4	14	86
	Jan. 10-11, 1905	1485.30	1473	1485.80	1449.25	.976	1.0087	36.55	2.9	16	84
	Total, 4 days....	6975.80	7160	7208.00	7068.03	....	....	139.97	....	....	....
	Av. per day	1743.95	1790	1802.00	1767.01	1.013	....	34.99	3.0	19	81
73....	S.A.B., Jan. 28, 1905....	2,082.30	2,252	2,264.30	2,225.81	1.069	1.0057	38.49	3.0	26	74
	Jan. 29, 1905....	2,746.90	2,958	2,966.80	2,928.23	1.066	1.0032	38.57	4.1	16	84
	Jan. 30, 1905....	2,763.20	2,725	2,735.20	2,698.27	.976	1.0036	36.93	3.8	16	84
	Jan. 31, 1905....	1,955.40	1,953	1,964.10	1,928.35	.986	1.0056	35.75	3.2	17	83
	Feb. 1, 1905....	1,075.90	1,026	1,037.80	1,001.89	.931	1.0119	35.91	2.9	17	83
	Total, 5 days....	10,623.70	10,914	10,968.20	10,782.55	....	....	185.65	....	....	....
	Av. per day.....	2,124.74	2,183	2,193.64	2,156.51	1.015	....	37.13	3.4	18	81
75 ...	S.A.B., Mar. 4, 1905...	1,973.30	1,496	1,508.20	1,469.59	.745	1.0079	38.61	3.3	16	84
	Mar. 5, 1905..	1,728.90	1,871	1,885.70	1 839.88	1.064	1.0077	45.82	3.2	16	84
	Mar. 6, 1905...	2,117.60	2,208	2,221.00	2,175.69	1.027	1.0057	45.31	3.6	14	86
	Mar. 7, 1905...	1,911.30	1,986	1,999.80	1,953.00	1.022	1.0070	46.80	3.4	17	83
	Mar. 8, 1905...	1,581.60	1,423	1,437.50	1,391.64	.880	1.0100	45.86	3.2	16	84
	Mar. 9, 1905...	1,702.00	1,611	1,624.40	1,580.70	.929	1.0081	43.70	3.3	13	87
	Mar. 10, 1905...	1,693.10	1,584	1,596.50	1,553.08	.917	1.0080	43.42	3.4	12	88
	Total, 7 days....	12,707.80	12,179	12,273.10	11,963.58	....	....	309.52	....	....	....
	Av. per day.....	1,815.40	1,740	1,753.30	1,709.08	.941	....	44.22	3.3	15	85
77....	S.A.B., Apr. 8, 1905..	2048.20	2552	2570.30	2528.15	1.234	1.0072	42.15	2.3	33	67
	Apr. 9, 1905..	1592.90	2156	2177.60	2122.94	1.333	1.0101	54.66	2.5	22	78
	Apr. 10, 1905..	1018.70	1554	1574.30	1520.30	1.492	1.0132	54.00	2.6	20	80
	Apr. 11, 1905..	962.00	1136	1156.60	1102.01	1.146	1.0178	54.59	2.7	17	83
	Total, 4 days....	5621.80	7398	7478.80	7273.40	....	....	205.40	....	....	....
	Av. per day.....	1405.45	1850	1869.70	1818.35	1.294	....	51.35	2.5	23	77
79....	H.E.S., Oct. 13, 1905...	782.50	1015	1027.20	996.08	1.273	1.0118	31.12	2.6	28	72
	Oct. 14, 1905...	399.90	840	859.10	809.96	2.025	1.0223	49.14	2.6	23	77
	Total, 2 days....	1182.40	1855	1886.30	1806.04	....	....	80.26	....	....	....
	Av. per day.....	591.20	928	943.15	903.02	1.527	....	40.13	2.6	25	74

[1] Not determined for individual days, calculated as shown on p. 28.

TABLE 193.—*Relations between amounts of drinking-water, water in urine, specific gravity, and total solid matter in metabolism experiments without food*—Continued.

Experiment number.	Subject and date.	(a) Am'nt of water consumed.	(b) Volume of urine.	(c) Am'nt of urine.	(d) Water in urine.	(e) Ratio of water in urine to water consumed (c÷a).	(f) Specific gravity.	(g) Total solids.	(h) Ratio of total solids to specific gravity.	Proportion of total solids. (i) Ash.	Proportion of total solids. (j) Organic matter.
		Gms.	*c.c.*	*Gms.*	*Gms.*			*Gms.*		*P.ct.*	*P.ct.*
80....	C.R.Y., Oct. 27, 1905...	132.80	1128	1147.40	1105.75	8.326	1.0169	41.65	2.2	45	55
	Oct. 28, 1905...	206.40	759	777.40	734.80	3.560	1.0287	42.60	2.5	29	71
	Total, 2 days....	339.20	1887	1924.80	1840.55	....	....	84.25	....	....	....
	Av. per day.....	169.60	944	962.40	920.28	5.426	....	42.12	2.4	37	63
81....	A.H.M., Nov. 21, 1905..	291.10	643	660.00	621.26	2.134	1.0264	38.74	2.3	33	67
	Nov. 22, 1905..	193.80	812	831.20	783.16	4.041	1.0230	48.04	2.6	23	77
	Total, 2 days.....	484.90	1455	1491.20	1404.42	...	....	86.78	....	....	....
	Av. per day.....	242.45	728	745.60	702.21	2.896	....	43.39	2.5	28	72
82....	H.C.K., Nov. 24, 1905..	857.80	561	575.70	538.57	.628	1.0361	37.13	2.5	26	74
	Nov. 25, 1905..	1092.90	1773	1795.00	1740.07	1.592	1.0127	54.93	2.4	30	70
	Total, 2 days....	1950.70	2334	2370.70	2278.64	....	....	92.06	....	....	....
	Av. per day.....	975.35	1167	1185.35	1139.32	1.168	....	46.03	2.5	28	72
83....	H.R.D., Dec. 5, 1905...	1467.10	1187	1204.50	1159.21	.790	1.0146	45.29	2.6	18	82
	Dec. 6, 1905...	884.20	1046	1065.00	1012.39	1.145	1.0186	52.61	2.7	17	83
	Total, 2 days	2351.30	2233	2269.50	2171.60	....	....	97.90	....	....	....
	Av. per day.....	1175.65	1117	1134.75	1085.80	.924	....	48.95	2.7	17	83
85....	N.M.P., Dec. 9, 1905..	704.50	[1] 1170	[2] 34.62 1188.00	[2] 33.37 1145.11	1.673	1.0154	[2] 1.25 42.89	2.4	29	71
	Dec. 10, 1905..	707.70	666	679.40	642.44	.908	1.0206	36.96	2.7	15	85
	Total, 2 days....	1412.20	1836	1902.02	1820.92	....	....	81.10	....	....	....
	Av. per day.....	706.10	918	951.01	910.46	1.289	....	40.55	2.6	22	78
89....	D.W., Jan. 10, 1906....	115.10	626	644.40	599.55	5.209	1.0296	44.85	2.4	30	70
	Jan. 11, 1906....	357.20	522	539.60	492.22	1.378	1.0338	47.38	2.7	16	84
	Total, 2 days....	472.30	1148	1184.00	1091.77	....	....	92.23	....	....	....
	Av. per day.....	236.15	574	592.00	545.89	2.312	....	46.12	2.6	23	77
	Av., all fasting experiments....... ..	1209.58	1350	1367.44	1323.77	1.095	....	43.67	2.8	[3] 21	[3] 79

[1] Includes volume of urine calculated as lost.
[2] Calculated. See p. 243.
[3] For 38 days.

CONSTITUENTS OF TOTAL SOLIDS.

To interpret intelligently the elimination of total solids, it is necessary to make a more careful study of the constituents of the solid matter in urine. The elimination of the total quantity of solids in the urine during inanition is affected in no slight measure by the amounts and character of the food for the day or two preceding the fast. This is especially true on the first days of fasting. If considerable amounts of sodium chloride are taken with the food, this will be excreted more or less rapidly on the first days of the fast. It is important, therefore, to determine if possible the nature of the total solids

eliminated. It is very much to be regretted that complete proximate analyses of urine could not have been made, as such data would undoubtedly make much clearer many troublesome points which arise in interpreting the results of the partial urinary analyses that were possible.

Ash.—In addition to the total solids, the ash was determined by incinerating the dried material at as low a temperature as possible, extracting the charred mass with water, and igniting the carbonaceous material. The aqueous extract was evaporated to small bulk, added to the ignited residue, and after completing the evaporation, the mass was dried for a few moments at a low red heat. Admittedly the errors in this determination are such as to make it only approximate, and the results are valuable only for the purposes of comparison, but since the same method was followed with all experiments, comparisons probably have more value than would be the case if different, though even more accurate methods, had been employed to determine the total solids and ash in the different experiments. The quantities of total solids are recorded in column *g* of table 193. The total ash as determined is recorded in table 194.

TABLE 194.—*Ash excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
59....	B.F.D., Dec. 18–20, 1903..	[1] 6.94	[1] 8.20	[1] 8.67	....	....	....	....
68....	A.L.L., Apr. 27–28, 1904..	[1] 10.91	[1] 11.60	....	....	....	....	....
69....	A.L.L., Dec. 16–19, 1904..	6.64	6.48	6.56	5.57	....	....	....
71....	S.A.B., Jan. 7–10, 1905..	7.65	6.06	5.85	5.94	....	....	....
73....	S.A.B., Jan. 28–Feb. 1, 1905	9.96	6.23	5.74	6.09	6.02	....	....
75....	S.A.B., Mar. 4–10, 1905..	6.03	7.54	6.44	7.80	7.48	5.85	5.27
77....	S.A.B., Apr. 8–11, 1905..	13.88	11.98	10.55	9.14	....	....	....
79....	H.E.S., Oct. 13–14, 1905..	8.73	11.17	....	....	....	....	....
80....	C.R.Y., Oct. 27–28, 1905..	18.93	12.52	....	....	....	....	....
81....	A.H.M., Nov. 21–22, 1905..	12.61	11.22	....	....	....	....	....
82....	H.C.K., Nov. 24–25, 1905..	9.67	16.33	....	....	....	....	....
83....	H.R.D., Dec. 5–6, 1905..	8.19	8.73	....	....	....	....	....
85....	N.M.P., Dec. 9–10, 1905..	[2] 12.83	5.57	....	....	....	....	...
89....	D.W., Jan. 10–11, 1906..	13.34	7.45	....	....	....	....	....
	Average.	10.45	9.36	7.30	6.91	6.75	5.85	5.27

[1] Not determined for individual days, calculated as shown on p. 28.
[2] Includes amount calculated in urine spilled. See p. 243.

As has been pointed out before, the ash in experiments Nos. 59 and 68, was apportioned over the different days, and hence the figures do not represent actual determinations. In all subsequent experiments, the ash and total solids for each day were determined.

Delaying for the present the discussion of the constituents of ash, the total ash determinations are of value in showing what proportion of the total

solids were of inorganic nature. The lowest amount of total ash recorded is on the last day of experiment No. 75, 5.27 grams; the highest amount is on the first day of experiment No. 80, 18.93 grams. While the amount of ash per day remains fairly constant in the longer fasting experiments, and except in experiments No. 68 and No. 77, never exceeds 10 grams per day, in the series of 2-day fasts, beginning with No. 79, much larger amounts of ash are eliminated, the lowest average being 8.46 grams, in experiment No. 83 and the highest, 15.73 grams, in experiment No. 80.

In the case of all the long fasting experiments except Nos. 68 and 77, the ash elimination is not far from 6 to 7 grams per day. On the first day of experiment No. 73, there is an unusually large amount of ash, 9.96 grams, while on the second day, it immediately falls to 6.23 grams. In experiment No. 68, the ash, although possibly erroneously distributed over the two days, is nevertheless for the average of the two days relatively large, and in experiment No. 77, the ash elimination varies from 13.88 grams on the first day to 9.14 grams on the last day.

Comparing experiments with the same subject, it may be seen that the ash in experiment No. 69 is but a little more than half as large as in the earlier experiment, No. 68, while with the series of experiments with S. A. B., the ash is practically constant at not far from 6 grams for all save the last experiment, No. 77, in which the average elimination is over 11 grams. In the series of 2-day experiments, the ash is usually smaller on the second day than on the first, although marked exceptions to this rule are seen in experiment No. 79, and especially No. 82.

It is, however, necessary to consider the data regarding the elimination of sulphur, phosphorus and chlorine for an intelligent interpretation of the elimination of ash.

The only data regarding the ash elimination during fasting with which we are familiar are the quantities in the urine of J. A. (9). On the last day with food the total ash of urine amounted to 23.0 grams; on the 5 fasting days the total ash eliminated was 14.7, 6.7, 5.7, 5.0, and 4.5 grams, respectively.

Although complicated by the fact that considerable amounts of sodium chloride were taken with some meat extract on each day of the experiments reported by Pettenkofer and Voit,[a] the ash determinations are here given. For the three one-day fasting experiments the amounts were 19.7, 18.89, and 14.40 grams, respectively.

Deducting the salts in the meat extract and the weight of sodium chloride used, the subject lost 2.1, 2.9, and 1.0 grams of ash per day in the three experiments.

Organic matter.—While as has been shown in the discussion regarding the total ash, the mineral constituents of fasting urines may vary considerably in

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[a] Zeit. f. Biologie (1866), 2, p. 479.

amount, especially on the first days of a fast, it is important to see what variations exist in the actual amounts of organic matter excreted per day. Since the organic matter is made up in large part of nitrogen containing material, it may be taken as a rough measure of the amount of protein metabolism, and therefore measurements of this total amount are of especial interest. The total organic matter of the urine is estimated by deducting the weight of ash from the weight of total solids, and hence the values thus obtained are affected by the errors incidental to the determinations of both ash and total solids. In determining total solids, it is probably true that the analyses give results which are somewhat too low, since even in drying in a vacuum, there is unquestionably loss of material. It is likewise true that in the determination of crude ash there must be more or less volatilization of inorganic material which tends to make the results for crude ash too low. Hence it is seen that the two most striking errors in the determinations of these two factors may be said to more or less compensate when the values thus obtained are used for the indirect determination of the total organic matter. It is reasonable to suppose then, that the determinations of organic matter are approximately correct. Furthermore, as has been pointed out previously, since the same method was employed for all experiments the results are strictly comparable.

TABLE 195.—*Total organic matter excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams*	*Grams.*
59....	B.F.D., Dec. 18–20, 1903..	[1] 39.36	[1] 46.60	[1] 49.08	....	....	....	....
68....	A.L.L., Apr. 27–28, 1904..	[1] 34.39	[1] 36.50	....	....	....	....	....
69....	A.L.L., Dec. 16–19, 1904..	29.41	38.59	40.93	36.21	....	....	....
71....	S.A.B., Jan. 7–10, 1905..	17.86	30.93	35.07	30.61	....	....	....
73....	S.A.B., Jan. 28–Feb. 1, 1905	28.53	32.34	31.19	29.66	29.89	....	....
75....	S.A.B., Mar. 4–10, 1905..	32.58	38.28	38.87	39.00	38.38	37.85	38.15
77....	S.A.B., Apr. 8–11, 1905..	28.27	42.68	43.45	45.45	....	....	....
79....	H.E.S., Oct. 13–14, 1905..	22.39	37.97	....	....	....	....	....
80....	C.R.Y., Oct. 27–28, 1905..	22.72	30.08	....	....	....	....	....
81....	A.H.M., Nov. 21–22, 1905..	26.13	36.82	....	....	....	....	....
82....	H.C.K., Nov. 24–25, 1905..	27.46	38.60	....	....	....	....	....
83....	H.R.D., Dec. 5–6, 1905..	37.10	43.88	....	....	....	....	....
85....	N.M.P., Dec. 9–10, 1905..	[2] 31.31	31.39	....	....	....	....	....
89....	D.W., Jan. 10–11, 1906..	31.51	39.93	....	....	....	....	....
	Average............	29.22	37.47	39.76	38.19	34.14	37.85	38.15

[1] Not determined for individual days, calculated as shown on p. 29.
[2] Includes amount calculated in urine spilled. See p. 243.

The amounts of organic matter found by deducting the total ash from the total solids are recorded for each day of each experiment (table 195). It is here to be noted that the apportionments of the total organic matter on

the different days of experiments Nos. 59 and 68, are open to the same objection as has been pointed out before, namely, that they are mathematical apportionments and do not represent actual determinations.

The, irregularity in the amounts of ash elimated on the different days of the different fasts, is likewise noted in the amounts of total organic matter. The lowest amount of organic matter, 17.86 grams, is on the first day of experiment No. 71, while the highest amount, 49.03 grams, is that mathematically apportioned to the third day of experiment No. 59. The largest amount actually determined, 45.45 grams, is on the last day of experiment No. 77. These limits, however, do not give a correct idea as to the relative constancy which seems to obtain in almost all the experiments with regard to the total amount of organic matter eliminated. In general the amount ranges somewhere between 30 and 40 grams. The greatest discrepancy generally appears on the first day of the longer fasts, after which the amount remains fairly constant for the different days of the fast. In all the experiments, the amount is larger on the second day than on the first.

In the fasts with S. A. B., the amounts of organic matter per day, especially after the first day are worthy of note. Excepting the first day, in experiments Nos. 71 and 73 the average amount is not far from 30 grams. It is about 38 grams in experiment No. 75, while in experiment No. 77, the total amount of organic matter per day for the last three days rises to nearly 44 grams, thus indicating that although on the second and succeeding days of fasting the amount is relatively constant, there may be wide variations during different fasts with the same subject, variations fully as wide as those obtained in the 2-day fasts with different subjects. It is noticeable that while the variations from day to day in the same fast after the first day are insignificant, such gross variations between different experiments with the same subject obtain.

The determinations of total solid matter and ash in the urine of three one-day fasting experiments reported by Pettenkofer and Voit[a] permit a computation of the amounts of organic matter. On the three days there were excreted 29.82, 25.26, and 31.89 grams of organic matter, respectively.

Further discussion of the organic matter of urine will be found with the data for the amounts of nitrogen, carbon, hydrogen of organic matter, and the proximate constituents of the urine.

PROPORTIONS OF ASH AND ORGANIC MATTER IN TOTAL SOLIDS.

The greater amount of mineral matter excreted on the first days of the fast produces wide variations in the proportions of organic and inorganic constituents of the total ash. In columns *i* and *j* of table 193, the proportions of ash and organic matter in the total solids are given. With the aid of these proportions the wide variations in the ratio between the total solids and the

[a] Loc. cit.

specific gravity discussed on page 354 can best be interpreted. The proportion of ash in total solids is as a rule, greatest on the first day and markedly less on the second day. In the longer fasts the proportion is relatively constant after the second day, although in experiment No. 77, an unusually high percentage of mineral matter was excreted on all four days. A ratio apparently exists between the proportion of mineral matter shown in column *i* and the relation between specific gravity and total solids as given in column *h* of the table. The higher the percentage of ash in the total solids, the lower the ratios shown in column *h*. This is especially noticeable in considering different days of the same experiment, but does not obtain for different experiments even with the same subject. In the shorter fasts the ratio between columns *i* and *h* is more nearly uniform. Indeed, even from experiment to experiment and with different subjects, the general rule may be noted that the higher the data in column *i*, the lower the corresponding data of column *h*. Thus the highest percentage of ash is 45 on the first day of experiment No. 80, and the lowest relation observed in the shorter experiments was 2.2 on the same day. Similarly, while the lowest percentages of ash occurred on the second days of experiments Nos. 83, 85, and 89, the highest ratios of total solids to specific gravity were observed on these days. These observations are fully in accord with the well known fact that the density of solutions of sodium chloride (a typical urine salt) is greater than that of solutions containing equal weights of urea (a typical organic urinary constituent).

NITROGEN.

The elimination in the urine of the partially oxidized protein in the form of a number of nitrogenous products has given to the determination of nitrogen an especial significance.

In all the earlier fasting experiments, the study of the nitrogenous ingredients of the urine has received by far the greatest attention of any individual factor. The collection and analysis of urine were comparatively simple matters, while the analyses of the respiratory products were in general precluded. Consequently we find in the literature of the subject a large number of determinations of nitrogen in fasting urines which are of especial interest in discussing the nitrogen elimination in the experiments here reported.

Recent investigations, notably those of Folin, have shown the importance of determining not only the total nitrogen but also the different nitrogenous ingredients, and of apportioning the nitrogen among these ingredients. In earlier experiments, however, the partition of the total nitrogen was not attempted and in the Middletown experiments here reported, it was impossible to determine the nitrogenous compounds directly, except in the instances where the determinations of creatine and creatinine, and a very few of uric acid, were made.

TOTAL NITROGEN.

In many of the earlier experiments on fasting made before the development of the Kjeldahl method, urea, the chief nitrogenous product of the urine, was determined either by the Liebig method, or by the action of sodium hypobromite, and the results thus obtained were considered as the measure of the total nitrogen elimination, although it is now recognized that other nitrogenous ingredients which are not precipitated by mercury salts or decomposed by sodium hypobromite are present in all urines. Indeed even in the long experiment with Succi at Florence, the method for determining nitrogen was distinctly open to objection, as has been pointed out by Munk (7).

TABLE 196.—*Amounts of nitrogen eliminated in urine daily by fasting subjects.*

Day of fast.	Succi.			J. A.	Cetti.	Breithaupt.	Landergren.	J.[1]	Sohn.	Subject I.[2]	Subject II.[2]	Flora Tosca.	Keller.[3]
	At Florence. 63.3K.	At Naples. 63.6K.	At Vienna.	67.8K.	57.0K.	60.1K.	78.6K.	80.2K.	58.6K.				74.7K.
	Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
Last food day.	[4]17.85	[5]8.99	....	22.41	13.49	13.02	19.71	....	20.98	7.15	....	13.99	....
1..	15.19	8.72	17.00	12.04	13.55	10.01	13.60	12.44	12.37	8.82	9.48	8.76	8.21
2..	12.13	8.45	11.2	12.72	12.59	9.92	13.43	5.67	12.37	10.09	11.36	8.38	6.75
3..	15.25	9.05	10.55	13.48	13.12	13.29	15.13	9.71	14.01	11.68	14.33	10.73	7.91
4..	14.08	8.51	10.8	13.56	12.39	12.78	13.87	9.47	[6]27.99	....	....	9.40	11.48
5..	14.12	9.87	11.19	11.34	10.70	10.95	....	....		....	....	7.87	....
6..	11.13	8.62	11.01	....	10.10	9.88	....	....	10.79	....	....	7.73	....
7..	10.31	7.62	8.79	....	10.89	....	....	....	14.50	....	....	6.11	....
8..	9.37	5.84	9.74	....	8.90	....	....	....	21.58	....	....	7.70	....
9..	8.56	6.90	10.05	....	10.83	....	....	....	....	....	....	7.35	....
10..	7.43	5.37	7.12	....	9.47	....	....	....	....	....	....	6.80	....

[1] Reported by A. Sadovyen (2).
[2] Reported by Schreiber & Waldvögel.
[3] Reported by A. Keller, Zeit. f. physiol. Chemie (1900), 29, p. 165.
[4] The figures in this column are given as corrected by Munk (7), p. 118.
[5] Given by Ajello and Solaro (6) as urea and here converted to nitrogen for purposes of comparison. Since the authors do not give the method employed, no attempt is here made to correct the figures.
[6] Amount for 2 days.

The urea determinations in these earlier experiments are therefore of little value for comparison with results obtained by the Kjeldahl method, but they do serve to show the approximate relative amount of urea on the different days of the same experiment.

Munk (7) has collected the references to the older literature of the excretion of nitrogen (usually expressed as urea) in the fasting insane, cases of œsophagus stricture, etc.

The subjects were in nearly all cases of small body-weight and the nitrogen output was frequently as low as four grams.

These figures are of value in indicating the possibilities of a minimum proteid katabolism, but the results of the determination of the nitrogen output of

persons in normal health made with modern methods of analysis are of much greater interest in connection with a discussion of the results obtained in the Middletown experiments.

The results of the more recent fasting experiments are given in table 196. Although the nitrogen excretion per kilo of body-weight is not given in the table, the data are readily obtained since the body-weight at the beginning of the fast [43] is given in the column headings.

Ranke [44] made three experiments on himself while fasting. Each experiment lasted one day. The amounts of nitrogen [45] eliminated were 10.4, 8.0, and 8.6 grams, respectively. In the last experiment no water was taken.

Pettenkofer and Voit [46] reported three experiments, each continuing one day in which the subject took no food other than a small amount of meat extract. The extract contained 1.2, 1.3, and 1.7 grams of nitrogen on the three days. The excretion of nitrogen in the urine was 12.5 (7.42 day, 5.09 night), 12.3 (6.72 day, 5.55 night) and 12.3 (5.55 day, 6.21 night) grams, respectively. From 10 to 15 grams of common salt were taken in connection with the meat extract. In the first two experiments the subject was resting, in the last he performed considerable muscular work. In both Ranke's and Pettenkofer and Voit's experiments, the determination of nitrogen was made by the Liebig method and hence did not represent the total urinary nitrogen.

It is a matter of historic interest that the first experiment made with Pettenkofer's respiration apparatus was that of Ranke studying the metabolism during inanition.

Likhachev [47] in a one-day fasting experiment found the total nitrogen output to be 8.52 grams.

In a 2-day fast Ritter [48] found that the subject excreted 11.68 and 12.96 grams of nitrogen, respectively.

In fasting experiments made in this laboratory and reported elsewhere,[49] the nitrogen excretion on the first day of fast in four experiments was 11.5, 16.0, 14.1, and 11.7 grams, respectively. The experiments were all made with the same subject. The first was after a carbohydrate diet during 4 days of rest; the second after a 4-day work experiment, in which the diet consisted largely of fats; the third likewise followed a 4-day work experiment with a fat diet; and the fourth was the first day of a 2-day fast experiment following a day of rest. On the second fasting day 12.2 grams of nitrogen were excreted.

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[43] In computing the nitrogen excreted per kilo of body-weight the average body-weight for each day of the fast should be used to secure the greatest accuracy. These weights may be obtained by means of the daily losses shown in tables 184 and 185.

[44] Archiv Anat. u. Physiol. (1862), p. 340.

[45] The total nitrogen was computed from the weights of urea and uric acid found.

[46] Zeit. f. Biol. (1866), 2, p. 478.

[47] Dissertation St. Petersburg (1893).

[48] Ritter, Münchener medic. Wochenschr., 1893, Nos. 31 and 32.

[49] U. S. Dept. of Agr., Office of Expt. Sta. Bul. 136, p. 120 (1903).

Woods & Merrill[60] report the average daily nitrogen excretion in a two-day fast as 11.96 grams.

Rosemann[61] found 9.89 grams of nitrogen in the urine on the first day of a fast.

In cooperation with Dr. A. R. Diefendorf the writer has presented * the results of a 6-day fast with an insane woman weighing 50 kilos. The daily nitrogen output was 4.19, 6.05, 6.38, 6.93, 6.16, and 4.41 grams.

Brugsch and Hirsch † have reported the total nitrogen output of a professional fasting woman weighing 56.3 kilos from the second to the sixteenth day of fasting. The output for the successive days of fasting beginning with the second was 8.41, 6.59, 7.78, 7.86, 7.82, 7.13, 6.20, 5.40, 4.38, 5.17, 5.38, 8.11, 5.96, 5.10, and 4.07 grams respectively.

Dr. Otto Folin ‡ reports the total nitrogen output on six days with a fasting man weighing 50 kilos as 4.4, 6.5, 7.7, 10.8, 11.0, and 12.2 grams respectively.

The total nitrogen excretion for each 24 hours of the fasting experiments here reported is given in table 197. For the details of the amounts of nitrogen excreted during the different periods of the day, reference is made to the tables in the statistical data for the experiments and to table 198.

The results of the nitrogen determinations in the urine of the subjects in the experiments made in this laboratory here reported show that the nitrogen eliminated on the first day of fasting ranges from 5.84 grams in experiment No. 71 to 13.25 grams, in experiment No. 83. The average for the first day for all the experiments is 10.03 grams. The unusually small amount of nitrogen eliminated in experiment No. 71 has been the subject of much investigation. An examination of the statistical tables shows that on that particular day, the nitrogen determinations by periods and in the composite sample agree as well as could possibly be expected. The weight of total solids observed on this day is lower than on any other day of fasting (see column *g* of table 193), and the weight of organic matter (see table 195) for this day is likewise much lower than on any other day. Hence there seems to be no doubt that there was an unusually low excretion of nitrogenous material in the urine on this day.

It is also of interest to note in this connection that the largest amount of organic matter on the first day of the fasting experiments, aside from the imperfectly apportioned amount in experiment No. 59, is found on the first day of experiment No. 83, i. e., it corresponds with the largest excretion of nitrogen.

Considering experiments with the same individual, S. A. B., in experiment No. 71, excreted the lowest amount (5.84 grams), of any of the subjects on the first day, and yet, on the first day of experiment No. 75, he excreted 12.24 grams, over twice as much as on the first day of experiment No. 71.

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[60] U. S. Dept. of Agr., Office of Expt. Sta. Bul. 85, p. 41 (1900).
[61] Archiv f. die ges. Physiol. (1897), 65, p. 360.
* Amer. Jour. Physiol. (1907), 18, p. 362.
† Zeit. f. experimentelle Pathologie u. Therapie (1906), 3, p. 640.
‡ Private communication.

The smallest amount of nitrogen excreted on any day was 5.84 grams on the first day of experiment No. 71.

TABLE 197.—*Nitrogen excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.		Fourth day.	
		Total.	Per kilogram of body weight.	Total.	Per kilogram of body wt.	Total.	Per kilogram of body wt.	Total.	Per kilogram of body wt.
		Grms.	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*	*Grms.*
59..	B. F. D., Dec. 18–20, 1903....	11.84	0.177	14.11	0.213	14.82	0.226	....	....
68..	A. L. L., Apr. 27–28, 1904....	12.26	.170	13.03	.184	....	....	....	....
69..	A. L. L., Dec. 16–19, 1904....	10.09	.137	14.26	.196	15.04	.209	12.97	0.182
71..	S. A. B., Jan. 7–10, 1905.....	5.84	.101	11.04	.194	13.10	.232	10.74	.193
73..	S. A. B., Jan. 28–Feb. 1, 1905.	10.29	.176	11.97	.208	11.54	.203	10.39	.185
75..	S. A. B., Mar. 4–10, 1905.....	12.24	.206	12.45	.211	13.02	.223	11.63	.202
77..	S. A. B., Apr. 8–11, 1905......	8.81	.144	10.78	.179	10.98	.186	11.45	.198
79..	H. E. S., Oct. 13–14, 1905....	8.11	.143	14.35	.259	....	....	....	....
80..	C. R. Y., Oct. 27–28, 1905....	7.78	.114	9.95	.149	....	....	....	....
81..	A. H. M., Nov. 21–22, 1905...	9.11	.148	13.05	.216	....	....	....	....
82..	H. C. K., Nov. 24–25, 1905....	9.38	.132	14.36	.205	....	....	....	....
83..	H. R. D., Dec. 5–6, 1905......	13.25	.239	13.53	.248	....	....	....	....
85..	N. M. P., Dec. 9–10, 1905.....	[1].32 11.05	} .170	11.35	.173	....	....	....	....
89..	D. W., Jan. 10–11, 1906......	9.99	.128	14.46	.188	....	....	....	....
	Average................	10.03	0.156	12.76	0.202	13.08	0.213	11.44	0.192

Experiment number.	Subject and duration of experiment.	Fifth day.		Sixth day.		Seventh day.	
		Total.	Per kilogram of body weight.	Total.	Per kilogram of body weight.	Total.	Per kilogram of body weight.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
73....	S. A. B., Jan. 28–Feb. 1, 1905.......	9.98	0.180	....	....	....	....
75....	S. A. B., Mar. 4–10, 1905...........	10.87	.191	10.74	0.190	10.13	0.181
	Average......................	10.43	0.186	10.74	0.190	10.13	0.181

[1] Determined for urine spilled. See p. 248.

In the records of the nitrogen output during fast given in table 196, aside from the uncorrected low figures of the Naples fast of Succi, the lowest nitrogen excretion is 5.67 grams on the second day with "J." The observations during the earlier days of fasting of so low an amount of nitrogen in the urine of the subjects "J" and "S. A. B." are strikingly exceptional. Even with the fasting girl, Flora Tosca, presumably of smaller body-weight, the nitrogen excretion is larger than in the two instances cited above.

The largest amount of nitrogen excreted on any fasting day in the Middletown experiments is 15.04 grams on the third day of experiment No. 69.

While the data in table 196 show that in general the excretion of nitrogen is less as the fast progresses, the determination of 21.58 grams of nitrogen in the urine of Sohn, on the eighth day of fast, is remarkable as being the largest excretion of nitrogen thus far observed with any fasting man.

It should further be noted, that inasmuch as Sohn was well nourished at the beginning of the fast and the experiment continued but eight days, we have not here to do with the premortal rise in nitrogen excretion occasionally observed in animals after a prolonged fast.

Excretion of nitrogen on days preceding fast.—In discussing the nitrogen excretion during fasting, the excretion on the day preceding the fast is of value in showing the rate of elimination when the ingestion of food ceased, since a large nitrogen excretion on the day preceding the fast would indicate a large nitrogen consumption. In certain cases the subjects of fasting experiments have made a special effort to eat an unusual amount on the day before the fast as a preliminary to the fast. Thus, the hypnotic subject of Hoover & Sollman (8) excreted 20.98 grams of nitrogen on the day before the fast began, while on the first day without food the nitrogen excretion fell to 12.37 grams. The nitrogen excreted by Landergren was 19.71 grams on the day before the fast and 13.60 grams on the first day of the fast. Perhaps the most marked difference in the excretion of the nitrogen on the day before the fast and the first fasting day thus far recorded is that of J. A., in the Stockholm laboratory (9), the nitrogen on the first day of the fast, 12.04 grams, being but a little more than one-half that excreted on the day before the fast, namely, 22.41 grams.

In nearly all of the Middletown experiments, the subjects were cautioned not to eat heartily during the day preliminary to a fast, and to eat no meat.

It was possible in many cases to measure the nitrogen excretion on the day preceding the fasting period.

For use in interpreting the results of the fasting days all the data available for the nitrogen determinations for the day before the fast and made in connection with these experiments are here given. In a number of instances, only the urine for the 12 hours before the fast began, was analyzed. In others, the analyses are made in the usual four periods for the day, the data being given in full below.

An examination of the data obtained with the subject S. A. B. for the preliminary night or day, shows that on the day preceding the first fast day of experiment No. 71 the subject excreted 3.21 grams of nitrogen between 7 p. m. and 7 a. m., an unusually small excretion for this subject, as is seen by comparison with the corresponding amounts of nitrogen eliminated during the night period on other preliminary days. The total nitrogen output for the day preceding experiment No. 73 was 12.50 grams, of which 7.153 grams was eliminated during the night from 7 p. m. to 7 a. m. On this preliminary night,

therefore, the nitrogen excretion was over twice that of the night preceding experiment No. 71. The corresponding elimination on the first day of the fast is also twice as great as in experiment No. 71.

On the day preceding experiment No. 75, S. A. B. excreted 19.495 grams of nitrogen, and the greatest elimination of nitrogen on the first day in his fasts occurred in this experiment.

Preliminary Nitrogen.

	Grams.
No. 59. Dec. 17-18, 1903:	
7 p. m. to 7 a. m....	6.234
No. 68.[1] Apr. 25-26, 1904:	
7 a. m. to 1 p. m....	4.332
1 p. m. 7 p. m....	5.098
7 p. m. 11 p. m....	3.302
11 p. m. 7 a. m....	5.720
Total for 24 hours..	18.452
Apr. 26-27, 1904 (2d day, No. 67):	
7 a. m. to 1 p. m....	3.766
1 p. m. 7 p. m....	4.714
7 p. m. 11 p. m....	2.991
11 p. m. 7 a. m....	4.949
Total for 24 hours..	16.420
No. 71. Jan. 6-7, 1905:	
7 p. m. to 11 p. m....	.702
11 p. m. 7 a. m....	2.508
No. 73. Jan. 27-28, 1905:	
7 a. m. to 1 p. m....	1.845
1 p. m. 7 p. m....	3.504
7 p. m. 11 p. m....	2.949
11 p. m. 7 a. m....	4.204
Total for 24 hours..	12.502

	Grams.
No. 75. Mar. 3-4, 1905:	
7 a. m. to 7 p. m....	11.239
7 p. m. 11 p. m....	2.893
11 p. m. 7 a. m....	5.363
Total for 24 hours..	19.495
No. 77. Apr. 7-8, 1905:	
7 a. m. to 1 p. m....	3.104
1 p. m. 7 a. m....	8.259
Total for 24 hours..	11.363
No. 79. Oct. 12-13, 1905:	
7 p. m. to 11 p. m....	1.95
11 p. m. 8^h33^m a. m.	2.70
No. 80. Oct. 26-27, 1905:	
7 a. m. to 7 a. m.....	7.78
No. 81. Nov. 20-21, 1905:	
7 a. m. to 7 a. m.....	8.61
No. 82. Nov. 23-24, 1905:	
7 a. m. to 7 a. m.....	11.20
No. 83. Dec. 4-5, 1905:	
7 a. m. to 7 a. m.....	8.719
No. 85. Dec. 8-9, 1905:	
7 a. m. to 7 a. m.....	16.597
No. 89. Jan. 9-10, 1906:	
7 a. m. to 7 a. m.....	13.684

[1] Experiment No. 68 followed immediately No. 67, a rest experiment with food.

Furthermore, on the day preceding experiment No. 77 the nitrogen elimination was 11.363 grams, while the nitrogen excretion on the first day fell to 8.81 grams. So far, therefore, as the different experiments with the same subject are concerned there would appear to be a relationship existing between the nitrogen elimination of the day preliminary to the fast and the nitrogen secretion of the first day.

When the series of 2-day fasting experiments for different individuals is considered the relationship is by no means as clear. The largest elimination on the day prior to the fast was that in experiment No. 85, 16.597 grams, and yet the nitrogen elimination on the first day of the fast was nearly 2 grams less than the maximum "first day" excretion which occurred in experiment No. 83. On the other hand, one of the lowest nitrogen excretions during the preliminary days was that on the day preceding the latter experiment.

Unfortunately in the series of 2-day fasts, duplicate experiments were not made with the same subject, and hence it is not possible to substantiate for the same individual the wide variation between the amounts of nitrogen excreted on the preliminary day and the first day of the fast.

It is furthermore much to be regretted that the data are also lacking for this comparison in the several fasts made by Succi.

Prausnitz (5), in a critical discussion of the subject, reports two experiments made with the same subjects in which the food on the day before the fast contained a much larger amount of protein in one case than in the other. The effect of the ingestion of increased amounts of protein on the nitrogen excretion of the first fasting day is very evident.

In fifteen 2-day fasting experiments on 12 different subjects, Prausnitz observed a nitrogen excretion on the first day of the fast varying from 4.6 [a] to 17.3 grams.

Sadovyen (2) reports also a second experiment with "J" in which the subject fasted 2 days without drinking water. The nitrogen excretion in the urine was for the day before the fast, 20.842 grams; for the first day of fast, 12.6 grams; and for the second fasting day 11.55 grams.

It is undoubtedly true that the nitrogen of protein ingested is not completely eliminated for some 36 hours, yet it is nevertheless a fact that a large excretion of nitrogen on the day preceding a fast may not necessarily be accompanied by a similar excretion of nitrogen on the first fasting day.

Although the nitrogenous excretion in the urine of the first fasting day is influenced to a marked degree by the protein ingestion of the day prior to the fast, the amounts of nitrogen eliminated on the second day of the experiments (table 197), are much more nearly constant ranging from 9.95 grams in experiment No. 80 to 14.46 grams in experiment No. 89. The average for all the experiments is 12.76 grams. Comparison of experiments with the same subject (S. A. B.) shows that the nitrogen excreted in experiment No. 77 on the second day was 10.78 grams and in experiment No. 75, 12.45 grams. On the second day of the other two experiments (Nos. 71 and 73) with S. A. B., it was 11.04 and 11.97 grams, respectively. Thus, while marked variations in the total quantity of nitrogen eliminated on the first day of the fast are observed in experiments with different individuals and in experiments with the same individual, on the second day of the fast the maximum difference in the amount of nitrogen excreted by the same individual in four fasts was but 1.7 grams.

Prausnitz (5) on the second day of fasting found in fifteen experiments with twelve subjects a nitrogen excretion of 13.0, 4.4, 10.6, 13.0, 11.0, 10.3, 12.5, 14.9, 13.8, 14.5, 12.6, 16.0, 14.9, 13.0, and 19.3 grams, an average of 12.9

[a] This unusually low nitrogen output, followed by a still lower amount (4.4 grams) on the second fasting day, has been the subject of special comment by Prausnitz.

grams. In comparing Prausnitz's results with those obtained in this laboratory, it is important to note that while wide differences in size, weight, and dietetic habits existed in Prausnitz's subjects those used in the Middletown experiments were as a rule college students eating more nearly the same fare.

The approaching constancy in the nitrogen elimination found on the second day of the fast with different individuals would incline one to the belief that on the third day the constancy would be even greater, yet an inspection of the results in table 197 shows that the variations ranged from 10.98 in experiment No. 77 to 15.04 in experiment No. 69. In the four experiments with S. A. B., the variations were from 10.98 to 13.10 grams, or a little over 2 grams. The average elimination for the six experiments was 13.08 grams.

Five experiments were made in which the fast was continued for 4 or more days. In these the nitrogen excretion varied from 10.39 to 12.97 grams, the average elimination for the five experiments being 11.44 grams. In the four experiments with S. A. B., the excretion varied from 10.39 to 11.63 grams, a difference of 1.24 grams. Not only is the variation for all the experiments much less, therefore, than on the previous days, but in different experiments with the same subject, there is a tendency for the nitrogen excretion to approach constancy on the fourth day.

Two experiments, both with S. A. B., continued for 5 or more days. The nitrogen in these experiments amounted on the fifth day to 9.98 and 10.87 grams, averaging 10.43 grams. One experiment continued during the sixth and seventh days and on these days there were excreted 10.74 and 10.13 grams of nitrogen, respectively.

Variations in nitrogen elimination as the fast progresses.—While as has been seen from the previous discussion, the gross fluctuations in the nitrogen excretion for the first day of different fasts render any interpretation of these results for short fasting experiments difficult, in the longer fasts the disturbing features of the first day are eliminated and the data are such as to permit of definite conclusions. In the majority of the experiments, there is an excretion of at least 2 grams more on the second day than on the first. In experiment No. 85, there was a greater excretion on the first day by 0.02 gram which, however, may well be within the limit of experimental error.

On the contrary, Prausnitz (5) found in three out of fifteen cases a diminished excretion on the second day. Of the thirteen fasting experiments cited in table 196 there was an increased nitrogen elimination on the second day of fasting in only three instances. The lack of harmony between these results and those obtained in the Middletown experiments can not readily be explained. Physical condition, previous dietetic habits, muscular exercise and other factors, yet too little known, may all have contributed to this result. The great uniformity in the results of the Middletown experiments would tend to uphold the view, that with like bodily activity and environment, the results should all be strictly comparable.

For the third day of each fast (table 197) the data show that in all cases (except experiment No. 73, where there was a diminished excretion of 0.43 gram), the nitrogen is greater on the third day than on the second, thus indicating an average progressive increase in the nitrogen excretion. For the average of all the experiments, the daily excretion is 10.03, 12.76, and 13.08 grams on the first, second, and third days, respectively. The evidence is sufficient to show a positive increase in nitrogen on the third day over the second amounting to 0.32 gram. This is also observed on the third day of the earlier fasts (table 196) with the single exception of the Vienna fast by Succi.

Of the five experiments which continued for 4 days or more, 4 were made with one subject, and with the exception of experiment No. 77, there was a decrease in the total nitrogen excretion on the fourth day as compared with the third. The average excretion for the five experiments was 11.44 grams, or 1.64 grams less than on the third day.

There was a further decrease of 1 gram in the nitrogen excreted on the fifth day while on the sixth and seventh days, it remained about the same.

In general, then, according to our experiments, the average nitrogen excretion on the second and third days is larger than on the first day, the maximum being reached on the third day. On the fourth and fifth days there is a steady diminution, and so far as the few observations recorded show, the excretion for the fifth, sixth, and seventh days is practically constant.

Relation of body-weight to nitrogen excretion.—Since proteid katabolism is proportional in general to the size of the body and in all probability to the active mass of protoplasmic tissue, it is important to note the nitrogen excretion per kilo of body-weight in the different fasting experiments. These have been also recorded in table 197.

On the first day of the fast, the variation in the nitrogen excreted per kilo of body-weight is from 0.101 gram in experiment No. 71 to 0.239 gram in experiment No. 83. The low excretion per kilo of body-weight in experiment No. 71 is to be expected from the unusually small amount of nitrogen excreted on this day. It is important to note that in experiment No. 75, made with the same subject, the amount of nitrogen excreted per kilo of body-weight is 0.206 gram. The average excretion for the first day of the fast is 0.156 gram.

On the second day the excretion per kilo varies from 0.149 gram in experiment No. 80 to 0.259 gram in experiment No. 79, averaging 0.202 gram. With the same individual, S. A. B., the variations ranged from 0.179 gram in experiment No. 77 to 0.211 gram in experiment No. 75. The excretion, then, per kilo of body-weight on the second day of the experiments is much more nearly constant than on the first day. On the third day, the per kilo excretion varies from 0.186 gram in experiment No. 77 to 0.232 gram in experiment No. 71, the average for the six experiments being 0.213 gram.

The variations on the fourth day of the fast are even smaller than on the third, ranging from 0.182 gram in experiment No. 69 to 0.202 gram in

experiment No. 75, the average for the 5 experiments being 0.192 gram. On the fifth, sixth, and seventh days, the average excretion per kilo of body-weight is 0.186, 0.190, and 0.181 gram, respectively.

The same differences that exist in the total excretion of nitrogen in the different experiments on the first day of the fast likewise appear in the excretion per kilo of body-weight. On the second and succeeding days, the excretion per kilo of body-weight is on an average much more nearly constant, and the maximum is reached on the third day.

In discussing the possible causes of variations in the elimination of nitrogen with different subjects, and indeed, in different experiments with the same subject, certain questions other than that as to the nitrogenous excretion on the day before the fast may be raised. For example, does the relative amount of protein in the body influence the rapidity with which it is disintegrated during the fast? In discussing the experiments on Cetti and Breithaupt, the Berlin investigators were of the opinion that the large increase in the elimination of nitrogen by these two subjects was due to the fact that they were not very fat and hence had a larger proportion of protein in the body. With the subject S. A. B., considerable light may be thrown upon the storage of protein inasmuch as between experiments Nos. 76 and 77 and also for a period of two weeks after experiment No. 77, a careful record was kept of all food ingested and the nitrogen was determined for each day's food, urine, and feces thus furnishing a complete balance of income and outgo of nitrogen. The details of these balances are reported beyond (see page 534), but it may be stated here that the results show that during the period between experiments Nos. 76 and 77, the subject actually gained 45.0 grams of nitrogen more than were lost during fasting experiment No. 75 and food experiment No. 76, thus indicating a marked storage of nitrogen in the body.

In the period following experiment No. 77 the data show that the body gained in addition to the nitrogen lost during the fast 11.1 grams of nitrogen.

Under these conditions, the increased amount of nitrogen is very noticeable and hence we should expect to find, that if the actual amount of nitrogenous material present in the body, be it either "organized" or "circulating," at the beginning of the experiment influences the subsequent nitrogen elimination during fasting, there would be an increase in the nitrogen elimination in the last experiment with this subject (experiment No. 77) over that excreted in the earlier ones. As a matter of fact, aside from the unusually low excretion noted on the first day of experiment No. 71, the absolute excretion, as well as the excretion per kilo of body-weight, was lowest rather than highest in experiment No. 77.

Unquestionably the gain in body-weight after fasting was due in large measure to the replacement of the water lost, but there must have been a not inconsiderable gain of fat, since the subject weighed considerably more at the end of the series of experiments than at the beginning. It may then be true

that the proportion of protein, when compared to that of fat, may have been no greater in the later than in the earlier experiments. The increase in water content of the body, however, may well lower the proportion of total protein in the body even with the material gain observed in the long nitrogen metabolism experiments.

Although the evidence is insufficient for drawing any definite conclusions, the results obtained imply that after the first fasting day the supply of reserve protein in the body has little, if any, effect on the subsequent excretion of nitrogen. Further experiments in which the partition of the nitrogen is more carefully studied are needed.[1]

Excretion of nitrogen in different periods of the day.—The samples of urine for the four periods of each day were separately analyzed during a portion of the series of experiments in the effort to obtain information concerning the distribution of nitrogen excretion.

These data are presented in table 198, in which the excretion for the two 6-hour day periods and the 12-hour night period are given. In this table the results for the periods from 7 p. m. to 11 p. m., and 11 p. m. to 7 a. m. are combined.

The proportions of the total nitrogen excreted during the day period and the night period have likewise been computed and the percentages expressed in the table.

The data in the table, which includes all the fasting experiments in which determinations by periods were made, show that during the period from 7 a. m. to 7 p. m. the per cent of total nitrogen may vary from 47.5 per cent, as on the second day of experiment No. 89, to 60.5 per cent, as on the first day of experiment No. 75. On the average 54.9 per cent of the total nitrogen is excreted during the day period.

There is a general tendency for the per cent of nitrogen excreted during the day period to increase perceptibly as the fast progresses in experiments Nos. 69 and 73. On the contrary, in experiment No. 75, the highest percentage is on the first, the lowest on the third day.

The proportions of nitrogen eliminated during the periods from 7 a. m. to 1 p. m. and 1 p. m. to 7 p. m. have not been shown separately in the table, but in general the larger excretion takes place during the period from 7 a. m. to 1 p. m., although the average for all the experiments is only about 2 per cent larger. Thus 51 per cent of the total nitrogen excreted during the first 12 hours of the day appears in the urine of the six hours from 7 a. m. to 1 p. m. A few noticeable exceptions are observed especially in the second day of experiment No. 59, both days of experiment No. 68 and in the second day of experiment No. 89.

[1] Folin's result on a fasting (see p. 364) man are of interest in that the subject had subsisted on a low nitrogen diet for some days before the fast began.

TABLE 198.—*Periodic distribution of nitrogen in urine in metabolism experiments without food.*

Experiment number.	Subject and date.	7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	Total for first 12 hours. Amt.	Total for first 12 hours. Proportion of total for 24 hours.	Total for last 12 hours. Amt.	Total for last 12 hours. Proportion of total for 24 hours.
59	B. F. D.	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*
	Dec. 18–19, 1903	3.59	3.22	6.81	57 5	5.03	42.5
	Dec. 19–20, 1903	3.37	4.19	7.56	53.6	6.55	46.4
	Dec. 20–21, 1903	4.37	4 17	8.54	57.6	6.28	42.3
	Total, 3 days	11.33	11.58	22.91	....	17.86	....
	Average per day	3.78	3.86	7.64	56.2	5.95	43.8
68	A. L. L.						
	Apr. 27–28, 1904	2.89	3.31	6.20	50.6	6.06	49.4
	Apr. 28–29, 1904	3.08	3.47	6.55	50.3	6.48	49.7
	Total, 2 days	5.97	6.78	12.75	....	12.54	....
	Average per day	2.99	3.39	6.38	50.4	6.27	4.96
69	A. L. L.						
	Dec. 16–17, 1904	2.45	2.51	4.96	49.2	5.13	50.8
	Dec. 17–18, 1904	3.94	3.80	7.74	54.3	6.52	45.7
	Dec. 18–19, 1904	4.32	4.03	8.35	55.5	6.69	44.5
	Dec. 19–20, 1904	4.12	3.47	7.59	58.5	5.38	41.5
	Total, 4 days	14.83	13.81	28.64	....	23.72	....
	Average per day	3.71	3.45	7.16	54.7	5.93	45.3
71	S. A. B.						
	Jan. 7– 8, 1905	....	....	3.29	56.3	2.55	43.7
	Jan. 8– 9, 1905	3.04	2.74	5.78	52.4	5.26	47.6
	Jan. 9–10, 1905	3.46	3.47	6.93	52.9	6.17	47.1
	Jan. 10–11, 1905	3.36	2.85	6.21	57.8	4.53	42.2
	Total, 4 days	9.86	9.06	22.21	....	18.51	....
	Average per day	[1]3.29	[1]3.02	5.55	54.5	4.63	45.5
73	S. A. B.						
	Jan. 28–29, 1905	2.58	2.56	5.14	50.0	5.15	50.0
	Jan. 29–30, 1905	3.13	3.23	6.36	53.1	5.61	46.9
	Jan. 30–31, 1905	3.18	2.72	5.90	51.1	5.64	48.9
	Jan. 31–Feb. 1, 1905	3.10	2.92	6.02	57.9	4.37	42.1
	Feb. 1–2, 1905	3.14	2.61	5.75	57.6	4.23	42.4
	Total, 5 days	15 13	14.04	29.17	....	25.00	....
	Average per day	3.03	2.81	5.83	53.9	5.00	46.1
75	S. A. B.						
	Mar. 4– 5, 1905	4.10	3.30	7.40	60.5	4.84	39.5
	Mar. 5– 6, 1905	3.82	3.30	7.12	57.2	5.33	42.8
	Mar. 6– 7, 1905	3.55	3.73	7.28	55.9	5.74	44.1
	Mar. 7– 8, 1905	3.36	3.39	6.75	58.0	4.88	42.0
	Mar. 8– 9, 1905	3.19	3.13	6.32	58.1	4.55	41.9
	Mar. 9–10, 1905	3.26	2.82	6.08	56.6	4.66	43.4
	Mar. 10–11, 1905	2.98	2.83	5.81	57.4	4.32	42.6
	Total, 7 days	24.26	22.50	46.76	....	34.32	....
	Average per day	3.47	3.21	6.68	57.7	4.90	42.3

[1] Average for 3 days.

TABLE 198.—*Periodic distribution of nitrogen in urine in metabolism experiments without food*—Continued.

Experiment number.	Subject and date.	7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	Total for first 12 hours.		Total for last 12 hours.	
				Am't.	Proportion of total for 24 hours.	Am't.	Proportion of total for 24 hours.
89	D. W.	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*
	Jan. 10–11, 1906	2.82	2.73	5.55	55.6	4.44	44.4
	Jan. 11–12, 1906	3.18	3.69	6.87	47.5	7.59	52.5
	Total, 2 days	6.00	6.42	12.42	....	12.03	....
	Average per day	3.00	3.21	6.21	50.8	6.02	49.2
	Average of above experiments	[1]3.36	[1]3.24	6.48	54.9	5.33	45.1

[1] Average for 26 days.

Data regarding the periodic excretion of nitrogen during fasting are also furnished in the experiments made in this laboratory and reported elsewhere.[83] In the 5 days during which the subject fasted, three 1-day experiments and one 2-day experiment, the proportion of total nitrogen excreted between 7 a. m. and 7 p. m. was 58.6, 52.7, 56.6 per cent for the three 1-day experiments, and 53.8 and 45.7 per cent for the 2 consecutive days of fasting.

The Swedish investigators in reporting the results for J. A. (9) give data for computing the proportion of total nitrogen excreted between 10 a. m. and 10 p. m. for the 5 days of the fast. The percentages are 59.1, 54.0, 50.7, 58.3, and 56.1, respectively.

In a one-day fast Rosemann[84] found 59.8 per cent of the total nitrogen was excreted between 7 a. m. and 7 p. m.

Influence of drinking-water on nitrogen excretion.—It has long been observed that the ingestion of large amounts of drinking-water results frequently in an increased nitrogen excretion. The significance of the relation between the volume of urine and the nitrogen excreted during fasting was pointed out by the Berlin scientists (7) in their discussion of the experiments on Cetti and Breithaupt. The influence of excessive amounts of drinking-water on fasting animals has also repeatedly been observed, and hence it is of importance to consider the volume of urine in the fasting experiments here reported, since the variations in volume may have an influence upon the excretion of nitrogen, and thus possibly account for the fluctuations in nitrogen excretion observed from day to day. The daily nitrogen excretion in grams and also the volume of urine are recorded in table 200, beyond.

[83] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136 (1903).
[84] Archiv f. die ges. Physiol. (1897), 65, p. 360.

A comparison of the data for the total 24 hours of a given experiment shows that in general large volumes of urine are accompanied by large amounts of nitrogen. For the consecutive days of each experiment this is generally true but no comparison is permitted for different experiments. This generalization is true for the large majority of the fasts. Especially is it true in the first 3 days of experiment No. 69, and the whole of experiments Nos. 71, 73, 75, 81, and 82. On the other hand, there are striking contradictions noticed more especially in experiment No. 77. In this experiment the largest volume of urine appears on the first day and is coincident with the smallest excretion of nitrogen, while on the last day the smallest volume of urine is accompanied by the largest excretion of nitrogen. A similar statement holds true for experiment No. 59. (See table 3.)

In considering this question, it is doubtful whether the 2-day experiments, influenced as they undoubtedly are by the food of the day before, can be considered as of much value. It thus appears that, while in the majority of the experiments it may be reasonably inferred that there was an increased elimination of nitrogen coincident with large volumes of urine, on the other hand, the data of experiments Nos. 59 and 77 render the conclusion doubtful.

The influence of drinking large quantities of water on the nitrogen excretion has been studied very carefully, the majority of the experiments, however, having been made with animals. All of the observations have demonstrated that with increased volume of urine there is an increased nitrogen excretion. The results have, however, permitted of two interpretations of the cause of the increase, and scientists have differed in their belief. According to one view the increase is due simply to the flushing out of the urea and other products preformed in the tissues, while the other maintains that the drinking of large amounts of water results in a stimulated protein katabolism. The more recent investigations of Hawk,[a] and Heilner,[b] have considered this problem in a more elaborate manner, stating not only the excretion of nitrogen but also of phosphorus, sulphur and chlorides.

An examination of the more recent experimental evidence leads to the conviction that experiments on fasting men especially with complete urine analyses would aid materially in settling this much disputed point. In spite of the fact that in several of the experiments here reported unusually large amounts of drinking-water were consumed, the conditions under which these experiments were made are such as in our judgment to preclude any direct conclusions regarding the influence of increased consumption of water on nitrogen excretion. It is important, however, in considering the causes for the variations in the nitrogen excretion on the different days, not to overlook the fact of the possible influence of the varying amounts of water consumed.

[a] Univ. of Pennsylvania Medical Bulletin (1904).
[b] Zeit. f. Biol. (1906), 47, p. 538.

In all the experiments with S. A. B., the volume of urine was large, in many cases very large. It should be noted, however, that the highest nitrogen excretion by this subject on any day was 13.10 grams, while in experiment No. 69 with A. L. L., an excretion of 15.04 grams of nitrogen appeared on the third day with but 743 cc. of urine. It would appear, then, that no very marked washing out of the urea or, indeed, increased protein katabolism followed the ingestion of the excessive quantities of water consumed by S. A. B. In the experiments with this latter subject the volume of urine was less than 1200 cc. on only three days. On the first day of experiment No. 71, the volume was 1149 cc. with a nitrogen excretion of 5.84 grams; on the last day of experiment No. 73, the volume was 1026 cc. with a nitrogen excretion of 9.98 grams; and on the last day of experiment No. 77, the volume was 1136 cc., and the nitrogen excretion was 11.45 grams.

The large amounts of drinking-water consumed by the subject S. A. B. were as a matter of fact not much, if any, greater than his customary consumption. While the data for the amount of drinking-water on the preliminary days is missing, the volumes of urine are recorded in the following table. For comparison the volumes on the first days of the experiments are included, as well as the nitrogen excretion for the corresponding days.

Experiment number.	Preliminary.		First day.	
	Volume.	Nitrogen.	Volume.	Nitrogen.
71......	[1]1482	[1]8.21	1149	5.84
73......	2265	12.50	2252	10.29
75......	1135	19.49	1496	12.24
77......	1111	11.36	2552	8.81

[1] For 7 p. m. to 7 a. m. only. The corresponding quantities for the same period on the first day of experiment 71 are: Volume = 170 cc; nitrogen = 2.55 grams.

The only noticeable increase in the volume of urine on the first day of fast is observed in experiment No. 77, in which nearly two and one-half times the volume of urine of the preliminary day was excreted. In spite of the influence of the large amount of water on this day the nitrogen excretion can in no wise be construed as indicating a flushing out of the nitrogenous wastes in the tissues.

A more detailed statement of the elimination of nitrogen by different periods in which the volume of urine as well as the total weight of nitrogen are taken into consideration is given in table 199.

While from the total volume of urine in 24 hours, it would appear that the nitrogen excretion followed roughly the volume of urine, when the volumes and excretion by periods are considered, the relationship is by no means as clear. Thus in experiment No. 73, first 6-hour period of the first day, there were passed 871 cc. of urine with but 2.58 grams of nitrogen. During the same period on the last day of the same experiment there was a little over half this

TABLE 199.—*Volume of urine excreted and nitrogen elimination by periods in metabolism experiments without food.*

Experiment number.	Subject and date.	7 a.m. to 1 p.m.		1 to 7 p.m.		First 12 hrs.		Last 12 hrs.	
		Volume of urine.	Nitrogen.	Volume of urine.	Nitrogen.	Volume of urine.	Nitrogen.	Volume of urine.	Nitrogen.
		c.c.	*Grms.*	*c.c.*	*Grms*	*c.c.*	*Grms.*	*c.c.*	*Grms.*
59	B.F.D., Dec. 18–19, 1903....	434	3.59	652	3.22	1086	6.81	431	5.03
	Dec. 19–20, 1903....	188	3.37	284	4.19	472	7.56	490	6.55
	Dec. 20–21, 1903....	252	4.37	298	4.17	550	8.54	358	6.28
	Total, 3 days...........	874	11.33	1234	11.58	2108	22.91	1279	17.86
	Average per day........	291	3.78	411	3.86	703	7.64	426	5.95
68	A.L.L., Apr. 27–28, 1904....	262	2.89	259	3.31	521	6.20	458	6.06
	Apr. 28–29, 1904....	217	3.08	217	3.47	434	6.55	388	6.48
	Total, 2 days...........	479	5.97	476	6.78	955	12.75	846	12.54
	Average per day........	240	2.99	238	3.39	478	6.38	423	6.27
69	A.L.L., Dec. 16–17, 1904....	112	2.45	119	2.51	231	4.96	206	5.13
	Dec. 17–18, 1904....	169	3.94	163	3.80	332	7.74	240	6.52
	Dec. 18–19, 1904....	250	4.32	203	4.03	453	8.35	290	6.69
	Dec. 19–20, 1904....	245	4.12	223	3.47	468	7.59	257	5.38
	Total, 4 days...........	776	14.83	708	13.81	1484	28.64	993	23.72
	Average per day........	194	3.71	177	3.45	371	7.16	248	5.93
71	S.A.B., Jan. 7– 8, 1905....	....	....	....	....	979	3.29	170	2.55
	Jan. 8– 9, 1905....	827	3.04	547	2.74	1374	5.78	635	5.26
	Jan. 9–10, 1905....	750	3.46	605	3.47	1355	6.93	1174	6.17
	Jan. 10–11, 1905....	640	3.36	519	2.85	1159	6.21	314	4.53
	Total, 4 days...........	[1]2217	[1]9.86	[1]1671	[1]9.06	4867	22.21	2293	18.51
	Average per day........	[1]739	[1]3.29	[1]557	[1]3.02	1217	5.55	573	4.63
73	S.A.B., Jan. 28–29, 1905....	871	2.58	549	2.56	1420	5.14	832	5.15
	Jan. 29–30, 1905....	815	3.13	937	3.23	1752	6.36	1206	5.61
	Jan. 30–31, 1905....	633	3.18	888	2.72	1521	5.90	1204	5.64
	Jan. 30–Feb. 1, 1905	605	3.10	765	2.92	1370	6.02	583	4.37
	Feb. 1–2, 1905....	451	3.14	241	2.61	692	5.75	334	4.23
	Total, 5 days..........	3375	15.13	3380	14.04	6755	29.17	4159	25.00
	Average per day.......	675	3.03	676	2.81	1351	5.83	832	5.00
75	S.A.B., Mar. 4– 5, 1905...	407	4.10	464	3.30	871	7.40	625	4.84
	Mar. 5– 6, 1905...	774	3.82	451	3.30	1225	7.12	646	5.33
	Mar. 6– 7, 1905...	500	3.55	807	3.73	1307	7.28	901	5.74
	Mar. 7– 8, 1905...	605	3.36	818	3.39	1423	6.75	563	4.88
	Mar. 8– 9, 1905...	310	3.19	568	3.13	878	6.32	545	4.55
	Mar. 9–10, 1905...	448	3.26	452	2.82	900	6.08	711	4.66
	Mar. 10–11, 1905...	389	2.98	550	2.83	939	5.81	645	4.32
	Total, 7 days..........	3433	24.26	4110	22.50	7543	46.76	4636	34.32
	Average per day.......	490	3.47	587	3.21	1078	6.68	662	4.90
89	D.W., Jan. 10–11, 1906....	219	2.82	195	2.73	414	5.55	212	4.44
	Jan. 11–12, 1906....	123	3.18	138	3.69	261	6.87	261	7.59
	Total, 2 days..........	342	6.00	333	6.42	675	12.42	473	12.03
	Average per day........	171	3.00	167	3.21	338	6.21	237	6.02
	Average of all above experiments.........	[2]442	[2]3.36	[2]458	[2]3.24	903	6.48	544	5.33

[1] For 3 days. [2] For 26 days.

volume of urine eliminated, but with a very considerable increase in the nitrogen. When the total quantity of urine for the first 12 hours of the first and last days of this experiment are taken into consideration a similar peculiarity may be observed. On the first and fourth days of experiment No. 75, in the first 12 hours there was a marked increase in the volume of urine accompanied by an actual decrease in the elimination of nitrogen. Similar anomalies are to be found in all of the experiments. It is clear, therefore, that the deduction that large volumes of urine induced by copious water drinking result in an invariable increase in the quantities of nitrogen excreted can not be made from the results of the Middletown experiments. It may be said, moreover, that the other conditions surrounding the experiment, namely, state of nutrition, body-weight, etc., vary too much in the different experiments to permit the deduction that copious water drinking does not affect the excretion of nitrogen.

Comparing the excretion of the day and the night periods in all the experiments given in table 199, there was on the average a greater excretion of nitrogen during the day than during the night. Considering the individual days, there were only two exceptions to this, namely, on the first day of experiment No. 69 and on the last day of experiment No. 89, on both of which days the excretion was somewhat greater during the night period. In one case the excretions for the day and for the night were identical. It is furthermore true that the volume of urine was, in general, greater during the day than during the night, there being but one exception to this, namely, on the second day of experiment No. 59.

In general, the larger amount of nitrogen excreted during the day period from 7 a. m. to 7 p. m. appears in the urine from 7 a. m. to 1 p. m., and an inspection of the volumes of urine shows that in experiments Nos. 73 and 75, the larger volume of urine is collected as a rule in the second period (1 p. m. to 7 p. m.). This is likewise true for experiment No. 59. In each of the experiments Nos. 68, 69, and 89, the volumes average about the same for both 6-hour periods of the day. Only in experiment No. 71 do we find a noticeably larger volume of urine during the first 6 hours. It is interesting to note that this difference in the volume of urine is accompanied by a larger increase in nitrogen during the first 6-hour period.

RATIO OF TOTAL SOLIDS TO NITROGEN.

The nitrogenous ingredients of urine are of organic origin and hence the larger the proportion of ash in the urine, the wider the variations in the ratio of total solids to nitrogen. The ratios, however, are of particular interest as use was made of certain of them in experiments Nos. 59 and 68 in apportioning the amounts of total ash and total solids over the several days of the experiments as explained above. The ratio of total solids to nitrogen or the number of grams of total solids present in the urine for each gram of nitrogen is shown in table 200.

TABLE 200.—*Ratio of total solids and organic matter to nitrogen in urine in metabolism experiments with and without food.*

Experiment number.	Subject and date.	(a) Volume.	(b) Nitrogen.	(c) Total solids.	(d) Ratio of total solids to nitrogen (c÷b).	(e) Organic matter.	(f) Ratio of organic matter to nitrogen (e÷b).
	Experiments without food.						
59	B. F. D., Dec. 18-21, 1903, average per day[1]	*c. c.* 1129	*Grams.* 13.59	*Grams.* 52.93	3.895	*Grams.* 45.00	3.311
68	A. L. L., Apr. 27-29, 1904, average per day[1]	901	12.65	46.70	3.692	35.45	2.802
69	A. L. L., Dec. 16-17, 1904	437	10.09	36.05	3.573	29.41	2.915
	Dec. 17-18, 1904	572	14.26	45.02	3.157	38.59	2.706
	Dec. 18-19, 1904	743	15.04	47.49	3.158	40.93	2.721
	Dec. 19-20, 1904	725	12.97	41.78	3.221	36.21	2.792
	Total, 4 days	2477	52.36	170.34	.....	145.14	.....
	Average per day	619	13.09	42.59	3.254	36.29	2.772
71	S. A. B., Jan. 7- 8, 1905	1149	5.84	25.51	4.368	17.86	3.058
	Jan. 8- 9, 1905	2009	11.04	36.99	3.351	30.93	2.802
	Jan. 9-10, 1905	2529	13.10	40.92	3.124	35.07	2.677
	Jan. 10-11, 1905	1473	10.74	36.55	3.403	30.61	2.850
	Total, 4 days	7160	40.72	139.97	.....	114.47	....
	Average per day	1790	10.18	34.99	3.437	28 62	2.811
73	S. A. B., Jan. 28-29, 1905	2252	10.29	38.49	3.741	28.53	2.773
	Jan. 29-30, 1905	2958	11.97	38.57	3.222	32.34	2.702
	Jan. 30-31, 1905	2725	11.54	36.93	3.200	31.19	2.703
	Jan. 31-Feb. 1, 1905	1953	10.39	35.75	3.441	29.66	2.855
	Feb. 1-2, 1905	1026	9.98	35.91	3.598	29.89	2.995
	Total, 5 days	10914	54.17	185.65	.....	151.61	.....
	Average per day	2183	10.83	37.13	3.428	30.32	2.800
75	S. A. B., Mar. 4- 5, 1905	1496	12.24	38.61	3.154	32.58	2.662
	Mar. 5- 6, 1905	1871	12.45	45.82	3.680	38.28	3.075
	Mar. 6- 7, 1905	2208	13.02	45.31	3.480	38.87	2.985
	Mar. 7- 8, 1905	1986	11.63	46.80	4.024	39.00	3.353
	Mar. 8- 9, 1905	1423	10.87	45.86	4.219	38.38	3.531
	Mar. 9-10, 1905	1611	10.74	43.70	4.069	37.85	3.524
	Mar. 10-11, 1905	1584	10.13	43.42	4.286	38.15	3.766
	Total, 7 days	12179	81.08	309.52	....	263.11	.....
	Average per day	1740	11.58	44.22	3.819	37.59	3.246
77	S. A. B., Apr. 8- 9, 1905	2552	8.81	42.15	4.784	28.27	3.209
	Apr. 9-10, 1905	2156	10.78	54.66	5.071	42.68	3.959
	Apr. 10-11, 1905	1554	10.98	54.00	4.918	43.45	3.957
	Apr. 11-12, 1905	1136	11.45	54.59	4.768	45.45	3.969
	Total, 4 days	7398	42.02	205.40	.....	159.85	.....
	Average per day	1850	10.51	51.35	4.886	39.96	3.802
79	H. E. S., Oct. 13-14, 1905	1015	8.11	31.12	3.837	22.39	2.761
	Oct. 14-15, 1905	840	14.35	49.14	3.424	37.97	2.646
	Total, 2 days	1855	22.46	80.26	.....	60.36	.....
	Average per day	928	11.23	40.13	3.573	30.18	2.687

[1] Not determined for individual days.

TABLE 200.—*Ratio of total solids and organic matter to nitrogen in urine in metabolism experiments with and without food*—Continued.

Experiment number.	Subject and date.	(a) Volume.	(b) Nitrogen.	(c) Total solids.	(d) Ratio of total solids to nitrogen (c÷b).	(e) Organic matter.	(f) Ratio of organic matter to nitrogen (e÷b).
	Experiments without food (cont'd).	c. c.	*Grams.*	*Grams.*		*Grams.*	
80	C. R. Y., Oct. 27–28, 1905	1128	7.78	41.65	5.353	22.72	2.920
	Oct. 28–29, 1905	759	9.95	42.60	4.281	30.08	3.023
	Total, 2 days	1887	17.73	84.25	.....	52.80	.....
	Average per day	944	8.87	42.12	4.749	26.40	2.976
81	A. H. M., Nov. 21–22, 1905	643	9.11	38.74	4.252	26.13	2.868
	Nov. 22–23, 1905	812	13.05	48.04	3.681	36.82	2.821
	Total, 2 days	1455	22.16	86.78	.....	62.95	.....
	Average per day	728	11.08	43.39	3.916	31.48	2.841
82	H. C. K., Nov. 24–25, 1905	561	9.38	37.13	3.958	27.46	2.928
	Nov. 25–26, 1905	1772	14.36	54.93	3.825	38.60	2.688
	Total, 2 days	2333	23.74	92.06	.....	66.06	.....
	Average per day	1167	11.87	46.03	3.878	33.03	2.783
83	H. R. D., Dec. 5–6, 1905	1187	13.25	45.29	3.418	37.10	2.800
	Dec. 6–7, 1905	1046	13.53	52.61	3.888	43.88	3.243
	Total, 2 days	2233	26.78	97.90	.....	80.98	.....
	Average per day	1117	13.39	48.95	3.656	40.49	3.024
85	N. M. P., Dec. 9–10, 1905	1170	{[1].32 11.05}	{[2]1.25 42.89}	3.882	{[2].89 30.42}	2.754
	Dec. 10–11, 1905	666	11.35	36.96	3.256	31.39	2.766
	Total, 2 days	1836	22.72	81.10	.....	62.70	.....
	Average per day	918	11.36	40.55	3.570	31.35	2.760
89	D. W., Jan. 10–11, 1906	626	9.99	44.85	4.489	31.51	3.154
	Jan. 11–12, 1906	522	14.46	47.38	3.277	39.93	2.761
	Total, 2 days	1148	24.45	92.23	.....	71.44	.....
	Average per day	574	12.23	46.12	3.771	35.72	2.921
	Average of experiments without food	1350	11.54	43.67	3.784	34.82	3.017
	Experiments with food.						
70	A. L. L., Dec. 20–21, 1904	1014	13.04	40.13	3.077	35.59	2.729
	Dec. 21–22, 1904	1026	9.84	35.66	3.624	29.30	2.978
	Dec. 22–23, 1904	608	10.15	38.54	3.797	29.61	2.917
	Total, 3 days	2648	33.03	114.33	.....	94.50	.....
	Average per day	883	11.01	38.11	3.461	31.50	2.861
72	S. A. B., Jan. 11–12, 1905	1487	10.66	33.07	3.102	29.48	2.765
74	S. A. B., Feb. 2–3, 1905	1509	10.74	32.96	3.069	29.47	2.744
	Feb. 3–4, 1905	1886	8.25	28.23	3.422	24.06	2.916
	Feb. 4–5, 1905	1597	6.78	25.52	3.764	20.70	3.053
	Total, 3 days	4992	25.77	86.71	.....	74.23	.....
	Average per day	1664	8.59	28.90	3.364	24.74	2.880

[1] Determined for urine lost. See p. 243.
[2] Calculated. See p. 243.

TABLE 200.—*Ratio of total solids and organic matter to nitrogen in urine in metabolism experiments with and without food*—Continued.

Experiment number.	Subject and date.	(a) Volume.	(b) Nitrogen.	(c) Total solids.	(d) Ratio of total solids to nitrogen (c÷b).	(e) Organic matter.	(f) Ratio of organic matter to nitrogen (e÷b).
	Experiments with food (cont'd).	c. c.	*Grams.*	*Grams.*		*Grams.*	
76	S. A. B., Mar. 11–12, 1905	1725	10.17	40.62	3.994	38.88	3.823
	Mar. 12–13, 1905	1308	7.15	23.25	3.252	21.41	2.994
	Mar. 13–14, 1905	1596	7.82	27.09	3.464	23.40	2.992
	Total, 3 days	4629	25.14	90.96	.....	83.69	.....
	Average per day	1543	8.38	30.32	3.618	27.90	3.329
	Average of experiments with food	1376	9.46	32.51	3.437	28.19	2.980

In experiments Nos. 59 and 68, only the average for the experiment is given as the determinations were made on the composite urine. In the other experiments, the determinations were made daily. The ratios range from 3.124 on the third day of experiment No. 71 to 5.353 on the first day of experiment No. 80. The average of all the experiments without food is 3.784. Comparing the individual days with this average ratio, the variations are in general very slight. The comparison shows even a greater uniformity in the ratios for the averages of the different experiments. The lowest average ratio is 3.254 in experiment No. 69 and the highest 4.886 in experiment No. 77.

The experiments on S. A. B. show that save in the case of experiment No. 77, the ratio is fairly constant. The two experiments with A. L. L. show similar uniformity. There is an unusually high ratio, 4.886, in experiment No. 77, which marks it as distinct from all the others.

RATIO OF ORGANIC MATTER TO NITROGEN.

The presence of varying amounts of ash and especially sodium chloride in the total solids of the urine would cause marked variations in the ratios of total solid matter to nitrogen. The nitrogen of urine is present in the organic matter and not in the ash of the urine, and hence if the ash be deducted from the total solids, the ratio of organic matter to nitrogen would be expected to be more nearly constant. Here again the ratio for experiments Nos. 59 and 68 are given only for the average per day for the whole experiment. The lowest ratio of organic matter to nitrogen is 2.646 on the second day of experiment No. 79. The highest ratio, 3.969, is found on the last day of experiment No. 77. For each gram of nitrogen excreted, there is on the average 3.017 grams of organic matter. The ratio of organic matter to nitrogen is, therefore, much more nearly constant than that of total solid matter to nitrogen.

The averages for the different experiments range from 2.687 to 3.802 grams. In the experiments with S. A. B., Nos. 71 and 73 show ratios that are not far from the average for all the experiments. In experiment No. 75 the ratio after the first day increases as the fast progresses and in experiment No. 77 there is an unusually high ratio on all days of the experiment. The excretion of non-nitrogenous organic matter is therefore indicated. While no tests were made for pathological constituents other than sugar or albumen (see p. 397) the possible formation of β oxybutyric acid and similar compounds must not be lost sight of in this connection. (See p. 395.)

EXCRETION OF CARBON IN THE URINE.

There is a considerable amount of carbon excreted in the urine, the total quantity of which, although relatively small when compared with the total excretion of carbon as carbon dioxide from the lungs, is nevertheless sufficiently large to be taken into consideration in obtaining the carbon balance.

The determination of nitrogen in urine is readily and rapidly made by the Kjeldahl method, but the determination of carbon presents a number of difficulties which render the absolute amount determined much less accurate than the corresponding determinations of nitrogen. Since, however, the amount of carbon excreted in the urine is only a small part of the total carbon elimination of the body, a relatively large error in the determination of carbon in the urine may exist without noticeable effect on the carbon balance.

Pettenkofer and Voit[*] determined the carbon elimination through the urine for the first fasting day, compared it with the total nitrogen and obtained as a result of three different experiments a ratio of carbon to nitrogen of 0.7.

In comparing the ratio of carbon to nitrogen obtained by other investigators, the differences in the methods employed may explain whatever differences in ratios appear. Munk (7) in determining the carbon in the urine dried 5 or 10 cc. of the acidulated urine with powdered copper oxide on the water bath and after mixing the material with coarsely powdered copper oxide, burned it in the combustion tube as usual. Determinations of the urine obtained in the experiment with Cetti were possible on only two days, namely, on the first and fifth fasting days. On the first day, during which 13.55 grams of nitrogen were eliminated, there were 12.63 grams of carbon giving the ratio $C:N = 0.9$. On the fifth fasting day, there were 14.85 grams of carbon and 10.69 grams of nitrogen, the ratio being 1.39. Munk states that in his opinion, the determinations made on the fifth day are too large.

The determinations of Breithaupt's urine were made very carefully and the ratios obtained are given in table 201, which also includes the results of the more recent experiments on J. A. (9) in which the carbon was determined by the moist combustion process of Kjeldahl.

[*] Zeit. f. Biol. (1866), 2, p. 479. The amount of carbon in the urine for each day was 8.25, 8.05, and 9.30 grams, respectively.

In only one of the several fasting experiments previously made in this laboratory[a] was the carbon determined in the urine. In experiment No. 36, which lasted one day there were 8.54 grams of carbon excreted and 11.34 grams of nitrogen. The ratio was C : N = 0.753.

The method of determining the carbon in urine at present in use in this laboratory is as follows: Five or 10 cc. of urine (the amount depending upon the specific gravity) is drawn into an aluminum dish and evaporated nearly to dryness in a vacuum desiccator. The partially dried mass is transferred from the aluminum dish to a copper combustion boat and dried again, prior to combustion in the Liebig combustion tube. In this process there is unquestionably a loss of nitrogenous and carbonaceous material, which it has as yet

TABLE 201.—*Ratio of carbon to nitrogen of urine in experiments with Breithaupt, Cetti, and J. A.*

Subject.	Day of fast.					
	First.	Second.	Third.	Fourth.	Fifth.	Sixth.
Breithaupt	0.88	0.95	0.83	0.68	0.79	0.89
Cetti	.90	....	....	....	1.39	....
J.A.	.667	.654	.734	.762	.822	....

NOTE.—It is important to note that in all three experiments, the ratio is above unity only on the fifth day of Cetti's fast, and the author distinctly questions the accuracy of the determination for that day.

been impossible to prevent. The method does, however, give as high results for carbon as any method with which we are familiar and consequently it has been used in all the experiments here given.

The total quantity of carbon and the total nitrogen excreted daily in the urine together with the ratio of carbon to nitrogen are given in table 202. It should be remembered that in experiments Nos. 59 and 68, the apportionment of the carbon over the different days was made according to the nitrogen elimination, and hence only the ratio for the total excretion for each experiment can be used. In all the other experiments, the carbon was determined for each day and hence the daily ratios may properly be used.

The lowest carbon elimination in any experiment was on the first day of experiment No. 71, 5.22 grams, while the highest was on the fourth day of experiment No. 77, 14.57 grams. Both these experiments were with the same subject and thus they serve to show the wide variations that may occur in the carbon elimination in the urine of a fasting man. The most striking variation in any one experiment is seen in experiment No. 77, when on the first day the elimination of carbon was 7.97 and on the fourth day, 14.57 grams. In considering the long experiments, it is noteworthy that the carbon elimination is invariably lowest on the first day and on the remaining days is relatively

[a] U. S. Dept. of Agr., Office of Expt. Sta. Bul. 136 (1903).

constant. The two most marked instances occur in experiments Nos. 77 and 75. In the former the carbon rose from 7.97 grams on the first day to 13.94 grams on the second, and in the latter from 8.14 grams on the first day to 11.50 grams on the second day, remaining practically constant thereafter.

TABLE 202.—*Ratio of carbon to nitrogen of urine in metabolism experiments without food.*

Experiment number.	Subject and date.	(a) Nitrogen.	(b) Carbon.	(c) [1] Ratio of carbon to nitrogen (b÷a).
		Gms.	*Gms.*	
59..	B.F.D., 1903: Dec. 18–21, average........	13.59	10.01	0.737
68..	A.L.L., 1904: Apr. 27–29, average........	12.65	10.06	.795
69..	A.L.L., 1904:			
	Dec. 16–17.....	10.09	8.31	.824
	Dec. 17–18.....	14.26	9.97	.699
	Dec. 18–19.....	15.04	10.37	.690
	Dec. 19–20.....	12.97	9.42	.726
	Average....	13.09	9.52	.727
71..	S.A.B., 1905:			
	Jan. 7– 8.....	5.84	5.22	.894
	Jan. 8– 9.....	11.04	8.29	.751
	Jan. 9–10.....	13.10	8.64	.660
	Jan. 10–11.....	10.74	7.73	.720
	Average....	10.18	7.47	.734
73..	S.A.B., 1905:			
	Jan. 28–29.....	10.29	7.47	.726
	Jan. 29–30.....	11.97	8.31	.694
	Jan 30–31.....	11.54	7.93	.687
	Jan. 31–Feb. 1..	10.39	7.66	.737
	Feb. 1–2......	9.98	7.89	.791
	Average....	10.83	7.85	.725
75..	S.A.B., 1905:			
	Mar. 4– 5.....	12.24	8.14	.665
	Mar. 5– 6.....	12.45	11.50	.924
	Mar. 6– 7.....	13.02	11.11	.853
	Mar. 7– 8.....	11.63	12.20	1.049
	Mar. 8– 9.....	10.87	12.65	1.164
	Mar. 9–10.....	10.74	12.02	1.119
	Mar. 10–11.....	10.13	11.34	1.119
	Average....	11.58	11.28	.974

Experiment number.	Subject and date.	(a) Nitrogen.	(b) Carbon.	(c) [1] Ratio of carbon to nitrogen (b÷a).
77..	S.A.B., 1905:	*Gms.*	*Gms.*	
	Apr. 8– 9.....	8.81	7.97	0.905
	Apr. 9–10.....	10.78	13.94	1.293
	Apr. 10–11.....	10.98	13.70	1.248
	Apr. 11–12.....	11.45	14.57	1.273
	Average....	10.51	12.54	1.193
79..	H.E.S., 1905:			
	Oct. 13–14.....	8.11	6.27	.773
	Oct. 14–15.....	14.35	10.22	.712
	Average....	11.23	8.24	.734
80..	C.R.Y., 1905:			
	Oct. 27–28.....	7.78	7.11	.914
	Oct. 28–29.....	9.95	9.02	.907
	Average....	8.87	8.06	.909
81..	A.H.M., 1905:			
	Nov. 21–22.....	9.11	7.52	.826
	Nov. 22–23.....	13.05	9.48	.726
	Average....	11.08	8.50	.767
82..	H.C.K., 1905:			
	Nov. 24–25.....	9.38	7.71	.822
	Nov. 25–26.....	14.36	10.77	.750
	Average....	11.87	9.24	.778
83..	H.R.D., 1905:			
	Dec. 5–6.......	13.25	9.76	.737
	Dec. 6–7.......	13.53	12.78	.945
	Average....	13.39	11.27	.842
85..	N.M.P., 1905:	[2].32	[3].22	
	Dec. 9–10.....	11.05	7.48	.677
	Dec. 10–11.....	11.35	8.22	.724
	Average....	11.36	7.96	.701
89..	D.W., 1906:			
	Jan. 10–11.....	9.99	8.38	.839
	Jan. 11–12.....	14.46	9.87	.683
	Average....	12.23	9.12	.746
	Average, 43 days.	11.54	9.57	.829

[1] Averages in this column obtained as $b \div a$.
[2] Determined for urine lost. See p. 243. [3] Calculated. See p. 243.

Thus it appears that the influences which affect the nitrogen elimination on the first day also affect the carbon elimination, and, indeed, in an even more striking manner.

The ratio of the carbon to the nitrogen presents wide variations, the minimum being observed on the third day of experiment No. 71, namely, 0.660, and the maximum on the second day of experiment No. 77, 1.293. While in experiments Nos. 73 and 75, there appears to be a tendency for the ratio to increase as the fast progresses, in experiment No. 77, the ratio remains almost constant after the first day. Practically the same can be stated regarding experiments Nos. 69 and 71. In the series of 2-day experiments, the ratios exhibit rather wide fluctuations on the different days of different experiments, but the averages for the two days of each experiment agree quite closely, the extremes being 0.909 and 0.701. There seems to be no general rule regarding the fluctuations seen in the ratios for the first and second days of the different experiments. Of special interest is the fact that with the same subject, S. A. B., the average ratio varied from 0.725 in experiment No. 73 to 1.193 in experiment No. 77. In fact, in the four experiments with S. A. B., there is a constancy in the ratio in the first two experiments and a marked increase in experiment No. 75, with a still further increase in experiment No. 77.

If the high ratios obtained in the Middletown experiments are the results of errors in determinations, they may be accounted for in only two ways—first, the determination of nitrogen may be low, and second, the determination of carbon may be high. Regarding the former point, it is hardly to be considered that the results as determined by the Kjeldahl method are too low. In fact, check tests with organic materials of known nitrogen content, which are frequently made, show the method and apparatus to be unusually accurate. Furthermore, in all these cases, the nitrogen was determined in all of the four periods as well as in the composite and the agreement was invariably very satisfactory.

On the other hand, a critical inspection of the method for determining carbon renders it almost impossible to believe that the carbon results are too high. While Munk (7), in discussing his determination of carbon in Cetti's urine, was of the opinion that the excessive amount of water in the dried urine might have escaped absorption in the first calcium chloride tube of the absorption system and thus be subsequently held in the potash tube, here the urine was completely dried in a vacuum desiccator and sulphuric acid was used for the first tube to absorb the moisture resulting from the combustion. Furthermore, it is the general experience in all laboratories that in organic elementary analysis, the determination of carbon is somewhat lower than the theoretical.

Considering, then, the possibilities of loss of carbon dioxide by the decomposition of urea or ammonium carbonate during the process of drying, it would appear that the results for carbon, if incorrect, are somewhat too low, and

hence the ratios from the experiments with S. A. B. too low rather than too high.

The apparently abnormal ratios between carbon and nitrogen in these fasting experiments have confirmation so far as the determination of the amount of carbon is concerned in the ratio of the energy to the nitrogen. (See discussion under energy section, p. 490.) From an inspection of the data given there, it would appear that the ratio of carbon to nitrogen observed is wholly in accord with what would be expected from the ratios of energy to nitrogen and hence support the view that the high ratios here observed actually exist and are not due to errors in analysis or computation.

The possibility of an excretion of non-nitrogenous or low-nitrogenous material in the urine, thereby increasing the ratio of carbon to nitrogen, will be considered in discussing the elimination of creatine and creatinine.

CREATININE AND CREATINE.

Although the pressure of other work in this laboratory precluded analyses of the urine to secure information as to the partition of the nitrogen, Prof. Lafayette B. Mendel, of Yale University, kindly offered to make determinations of creatinine in the urine of experiments Nos. 73 and 74, suggesting that, in view of the recent appearance of Folin's theory of protein metabolism, determinations of the creatinine output of a fasting man would be of interest. A Dubosc colorimeter was obtained later and in all experiments subsequent to No. 74, the determinations were made in this laboratory.

Observations regarding the excretion of creatinine by fasting men have hitherto been confined to those of Baldi[a] and E. and O. Freund (10) on Succi, and by Van Hoogenhuyze and Verploegh (11) on a fasting girl. Baldi determined the creatinine elimination of Succi during the Florence fast by using the Neubauer method. On the seventh fasting day he found by this method 0.8011 gram of creatinine; on the twelfth, 0.7159 gram, and on the seventeenth, 0.4029 gram. After the seventeenth day, although creatinine could be determined qualitatively, it was not present in weighable amounts.

E. and O. Freund (10) likewise using the Neubauer method, determined the creatinine in the 21-day fast of Succi made in Vienna in 1896. According to their observations, the creatinine-nitrogen increased from 0.134 gram, on the first day to 0.578 gram, on the ninth day. The authors explain that the increase was probably caused by the exercise which Succi had with the sabre. On the tenth and eleventh days the creatinine-nitrogen fell rapidly. The twelfth day the output was but 0.08 gram. The decrease continued as the fast progressed, there being but 0.025 gram of creatinine-nitrogen excreted on the twenty-first day.

[a] Centralblatt f. klin. Medic. (1889), 10, p. 651.

Folin's[a] method for determining creatinine was used in the experiments with the fasting girl Flora Tosca. It is not stated definitely whether the urine was heated with hydrochloric acid before making the colorimetric observations. It is not, therefore, clear whether the amounts of creatinine include preformed creatine (as creatinine). Urine was collected in three periods of the day, from 10 a. m. to 4 p. m., 4 p. m. to 10 p. m., and 10 p. m. to 10 a. m. The last food was taken on the morning of June 10, 1905, and no more food was consumed until June 25. During the fasting period the subject remained at rest, save for 2 hours of gymnastic exercise on June 17. The quantity of creatinine in the urine on the day preceding the fast was 1.087 grams. The excretion decreased regularly and rapidly to the eighth day. On the day when muscular exercise was taken, the creatinine amounted to only 0.469 gram, while on the following day it rose to 0.689 gram. During the three days before muscular work was done a total of 1.662 grams was excreted; the total output for the three following days was 2.006 grams. The excretion then decreased to about 0.5 gram daily, remaining fairly constant during the remainder of the fast.

The new method of Folin for determining creatinine by means of the Jaffé reaction was used in many of the experiments here reported. This reaction is not given by creatine and hence it is necessary to heat the urine with hydrochloric acid to convert the creatine to creatinine. A determination of the creatinine in the urine before and after heating with hydrochloric acid gives, therefore, a measure of the amount of creatine (in terms of creatinine) which is present in the urine. It has been found in a large number of experiments, that the amount of preformed creatine in the urine is normally very small.

In table 203 the results of the creatine and creatinine determinations are given for the fasting experiments, for the two food experiments following fasting, namely Nos. 74 and 76, and for the two nitrogen metabolism experiments Nos. 1 and 2 made with S. A. B. In all experiments after No. 74, the determinations were generally made of both preformed and total creatinine and consequently in the last column of the table is recorded the weight of creatine (expressed as creatinine) excreted.

In experiments Nos. 73 and 74 the quantities of urine that could be spared for samples to be sent to New Haven were small, and hence the results were not as satisfactory as those made in our laboratory where analyses could be repeated as desired, and where they could be made on the day immediately following the collection of the sample. It is, therefore, more especially with the experiments beginning with No. 75 that the results are of especial importance.

The excretion of total creatinine, namely, preformed creatinine plus creatinine formed by heating the creatine of the urine with acid, remains singularly constant on all days of the fast, even during the 7-day fast, experiment No. 75.

[a] Zeitschrift f. physiol. Chemie (1904), 41, p. 223.

The quantity of preformed creatinine on the contrary, is seen to diminish as the fast progresses. In general, the diminution is quite regular for the first 4 days of the experiment and indeed, when the results for experiments Nos. 75 and 77 are compared, the agreement between the two experiments is remarkable. On the fifth day of experiment No. 75, the lowest excretion of preformed creatinine is observed. After this day, the excretion increases slightly until the end of the experiment.

TABLE 203.—*Creatinine and creatine excreted in urine in metabolism experiments with and without food.*

Experiment number.	Subject and date.	Creatinine. Total, including creatine.	Creatinine. Preformed.	Creatine.[1]	Experiment number.	Subject and date.	Creatinine. Total, including creatine.	Creatinine. Preformed.	Creatine.[1]
73..	S.A.B., 1905:	*Gms.*	*Gms.*	*Gms.*	77..	S.A.B., 1905:	*Gms.*	*Gms.*	*Gms.*
	Jan. 28-29....	1.250	....	....		Apr. 8- 9...	1.342	1.202	0.140
	Jan. 29-30....	1.200	....	....		Apr. 9-10...	1.343	1.027	.316
	Jan. 30-31....	.871	....	....		Apr. 10-11...	1.383	.968	.415
	Jan. 31-Feb. 1.	.791	....	....		Apr. 11-12...	1.386	.848	.538
	Feb. 1-2.....	1.110	....	....	N2..	S.A.B., 1905:			
74..	S.A.B., 1905:					Apr. 12-13...	1.450	1.407	.043
	Feb. 2-3......	1.06	....	....		Apr. 13-14...	1.420	1.384	.036
	Feb. 3-4......	1.01	....	....		Apr. 18-19...	1.334	1.300	.034
	Feb. 4-5......	.86	....	....	79..	H.E.S., 1905:			
75..	S.A.B., 1905:					Oct. 13-14...	1.225	1.212	.013
	Mar. 4- 5....	1.237	1.212	0.025		Oct. 14-15...	1.418	1.254	.164
	Mar. 5- 6....	1.294	1.061	.233	80..	C.R.Y., 1905:			
	Mar. 6- 7....	1.407	.956	.551		Oct. 27-28...	1.505	1.505	....
	Mar. 7- 8....	1.325	.865	.460		Oct. 28-29...	1.538	1.398	.140
	Mar. 8- 9....	1.214	.712	.502	81..	A.H.M., 1905:			
	Mar. 9-10....	1.318	.733	.585		Nov. 21-22...	1.226	1.184	.042
	Mar. 10-11....	1.270	.782	.488		Nov. 22-23...	1.357	1.229	.128
76..	S.A.B., 1905:				82..	H.C.K., 1905:			
	Mar. 11-12....	1.411	1.137	.274		Nov. 24-25...	1.726	1.643	.083
	Mar. 12-13....	....	1.292	....		Nov. 25-26...	1.795	1.730	.065
	Mar. 13-14....	....	1.346	....	83..	H.R.D., 1905:			
N1..	S.A.B., 1905:					Dec. 5-6.....	1.317	1.217	.100
	Mar. 14-15....	1.566	1.493	.073		Dec. 6-7.....	1.363	1.129	.234
	Mar. 15-16....	....	1.433	....	85..	N.M.P., 1905:			
	Mar. 16-17....	....	1.251	....		Dec. 9-10...	[2]1.543	[2]1.525	[2].018
	Mar. 21-22....	....	1.487	....		Dec. 10-11...	1.703	1.541	.162
	Mar. 22-23....	....	1.523	....	89..	D.W., 1906:			
						Jan. 10-11...	2.091	2.028	.063
						Jan. 11-12...	1.966	1.922	.044

[1] In terms of creatinine.
[2] Does not include possible amount in urine lost.

While the quantity of preformed creatinine gradually diminishes as the fast progresses, the amount of creatine, which in normal urines is extremely small, gradually increases, and on the sixth day of the fast (No. 75), there is excreted 0.585 gram of creatine (expressed in terms of creatinine).

The same may be said regarding the excretion of creatine in experiment No. 77. In the shorter experiments, the amount of total creatinine, in general, remains fairly constant. The results for creatine show a greater amount on the second day of the experiment than on the first day in five of the experiments, while in Nos. 82 and 89, there is but a small quantity of creatine excreted on both days, the lesser amount being excreted on the second day.

The interpretation of these results, according to Folin's theory of protein metabolism, would indicate that the amount of tissue protein disintegrated (endogenous protein katabolism), even during a prolonged fast, remains constant from day to day. While on the one hand it might reasonably be expected that the tissue protein would be more rapidly katabolized during fasting, when the body has to subsist on its own material, than during the ingestion of food, yet on the other hand it is not difficult to conceive that during fasting the body has the power to protect its organized or tissue protein more thoroughly than when well supplied with food. Hence the constancy in the total creatinine elimination, viewed in the light of the Folin theory, furnishes no evidence to show either an increased or diminished endogenous protein katabolism during inanition.

While with a normally fed individual creatine is wholly converted by the body to creatinine before being excreted, apparently with the fasting individual the body gradually loses this power of converting creatine to creatinine as the fast progresses.[a]

The data thus far obtained are insufficient to show clearly the true significance of this abnormality in the power of the body to convert creatine. Further experiments are necessary to solve this specific problem. The fact, however, that during prolonged fasting the body loses to a marked degree the power of converting creatine to creatinine is suggestive in interpreting results of the katabolism of tissue protein and also of the synthetic power of the body in general. It is furthermore clear that while the majority of the short experiments indicate a loss of power of conversion, experiments should be continued for more than two days to throw definite light on this subject.

In a recent series of experiments made by Folin,[b] he has advanced the suggestion that creatine when ingested is a food serving a purpose different from that of the ordinary amino acids. These experiments imply that when the body is flooded with protein, as after a diet rich in nitrogenous material, the ingestion of creatine is followed by its immediate excretion, while creatine ingested after the supply of reserve protein has been depleted by a low protein diet is wholly retained in the body. Neither the creatine, creatinine, nor, indeed, the total nitrogen excretion are affected by the ingestion of creatine under these conditions.

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[a] For another possible explanation of the increase in creatine excretion see p. 458.
[b] Festschrift für Olof Hammersten, Upsala (1906).

Somewhat similar results were obtained by Klercker.[a]

While in some ways it is difficult to harmonize the results of Folin and Klercker with those here reported, both sets of experiments emphasize the fact that it is difficult at times for the body to convert creatine to creatinine.

It would appear, then, that if the body possesses a ferment which can dehydrate creatine to creatinine, the secretion or possibly the activity of this ferment is markedly decreased by fasting.

In this connection, it is important to observe the rapidity with which the body recovers its power to convert creatine to creatinine after the ingestion of food. Thus, in experiment No. 76, the excretion of creatine which on the day previous (seventh fasting day) was 0.488 gram was reduced to 0.274 gram, although this day differs in no wise from the day preceding except in that the following amounts of food were eaten: 651 grams modified milk, 123 grams apple, 313 grams orange juice, 178 grams shredded wheat, and 10 grams gluten crackers.

Unfortunately, the determinations of total creatinine on the two following days of experiment No. 76 could not be made, but from the determinations of creatinine, made before heating with acid, the deduction may be made that the normal elimination of creatinine had been reached on the second day of the experiment, and that in all probability the amount of creatine excreted on this day was very small. In fact, 3 days later, namely, March 14-15, the amount of creatine was again determined and found to be but 0.073 gram. The power to convert creatine was regained in an even more striking manner in nitrogen metabolism experiment No. 2. The creatine excretion (as creatinine) of April 11-12 was 0.538 gram. On the next day with food (April 12-13) it was only 0.043 gram. This practical disappearance of creatine from the urine was incidental to the ingestion of food on the first day that the subject was out of the respiration chamber and subsisting on a creatine-free diet of his own selection. The kinds and amounts of food eaten this day are given in table 176.

While in all cases, the creatine practically disappeared upon the ingestion of food, there was no marked increase in the total creatinine from day to day, which indicates that the creatine had simply been converted to creatinine and excreted as such. In all of the food experiments following fast, care was taken to avoid foods containing creatine and creatinine, though throughout the nitrogen metabolism experiments the diet was practically creatine-free, as the subject ate meat on only one or two occasions. On all days when samples were taken for creatinine determinations no meat had been taken for 24 hours.

Excretion of creatinine by periods.—In experiments Nos. 75 and 76 the determinations of preformed creatinine, i. e., creatinine determined before heating with acid, were made on the samples collected during each period.

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[a] Zeit. f. gesammte Biochemie (1906), 8, p. 59.

The data, therefore, furnish evidence as to the excretion of creatinine during the different periods of the day. Such determinations as are available have been placed in table 204. A comparison of the total amount in 24 hours as recorded in this table and the corresponding amount as recorded in table 203 shows slight discrepancies on the different days. The record in table 203 is that determined on the daily composite sample, while that in table 204 is the sum of the amounts of preformed creatinine for the four periods of each day. When the large volumes of urine are taken into consideration the agreement is as satisfactory as could well be expected. The table shows the actual amount of preformed creatinine excreted in the periods from 7 a. m. to 1 p. m., from 1 p. m. to 7 p. m., and the total for the first 12 hours of the day, the amount for the night being given in one column as was the case in table 198, showing the distribution of nitrogen by periods. The unequal division of the night into a 4-hour and an 8-hour period makes this presentation of the results more satisfactory.

TABLE 204.—*Preformed creatinine by periods eliminated in urine in metabolism experiments Nos. 75 and 76.*

Experiment number.	Subject and date.	7 a.m. to 1 p.m.	1 p.m. to 7 p.m.	Total for first 12 hours.		Total for last 12 hours.		Total amount in 24 hours.
				Am'nt.	Proportion of total for 24 hours.	Am'nt.	Proportion of total for 24 hours.	
	1905.	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*
75...	S.A.B.:							
	Mar. 4– 5	0.340	0.330	0.670	54.6	0.558	45.4	1.228
	Mar. 5– 6	.313	.256	.569	54.4	.476	45.6	1.045
	Mar. 6– 7	.236	.222	.458	52.5	.415	47.5	.873
	Mar. 7– 8	.243	.212	.455	58.3	.325	41.7	.780
	Mar. 8– 9	.169	.148	.317	48.8	.332	51.2	.649
	Mar. 9–10	.157	.158	.315	48.5	.335	51.5	.650
	Mar. 10–11	.148	.175	.323	44.4	.405	55.6	.728
76...	S.A.B.:							
	Mar. 11–12	.263	.302	.565	50.7	.549	49.3	1.114
	Mar. 12–13	.365	.304	.669	54.3	.564	45.7	1.233
	Mar. 13–14	.348	.350	.698	51.9	.648	48.1	1.346

Considering first the apportionment of the total preformed creatinine excretion between the day and the night periods, the figures show that during the day the per cent may be as low as 44.4 of the total and as high as 58.3. The percentage excreted during the day has a distinct tendency to become lower as the fast progresses. Aside from the 58.3 per cent on the fourth day of the fast, the decrease is very constant. On the ingestion of food, the excretion of performed creatinine during the first 12 hours of the day averages about 52 per cent.

TABLE 205.—*Proportions of nitrogen of total creatinine and of creatine in total nitrogen excreted in urine in metabolism experiments with and without food.*

Experiment number.	Subject and date.	(*a*) Nitrogen in total creatinine.	(*b*) Nitrogen in creatine.	(*c*) Total nitrogen in urine.	Proportion of total nitrogen. (*d*) In total creatinine (*a* *c*).	Proportion of total nitrogen. (*e*) In creatine (*b*+*c*).
	1905.	*Gram.*	*Gram.*	*Grams.*	*Per ct.*	*Per ct.*
73	S.A.B., Jan. 28–29	0.465	....	10.29	4.52	....
	Jan. 29–30	.447	....	11.97	3.73	....
	Jan. 30–31	.324	....	11.54	2.81	....
	Jan. 31–Feb. 1	.294	....	10.39	2.83	....
	Feb. 1– 2	.413	....	9.98	4.14	....
74	S.A.B., Feb. 2– 3	.395	....	10.74	3.68	....
	Feb. 3– 4	.376	....	8.25	4.56	....
	Feb. 4– 5	.320	....	6.78	4.72	....
75	S.A.B., Mar. 4– 5	.460	0.008	12.24	3.76	0.07
	Mar. 5– 6	.482	.075	12.45	3.87	.60
	Mar. 6– 7	.524	.177	13.02	4.03	1.36
	Mar. 7– 8	.493	.148	11.63	4.24	1.27
	Mar. 8– 9	.452	.161	10.87	4.16	1.48
	Mar. 9–10	.491	.188	10.74	4.57	1.75
	Mar. 10–11	.473	.157	10.13	4.67	1.55
76	S.A.B., Mar. 11–12	.525	.088	10.17	5.16	.87
	Mar. 12–13	....	....	7.15	....	....
	Mar. 13–14	....	....	7.82	....	....
1 Nitrogen metabolism	S.A.B., Mar. 14–15	.583	.023	12.61	4.62	.18
77	S.A.B., Apr. 8– 9	.499	.045	8.81	5.67	.51
	Apr. 9–10	.500	.101	10.78	4.64	.94
	Apr. 10–11	.515	.133	10.98	4.69	1.21
	Apr. 11–12	.516	.173	11.45	4.51	1.51
2 Nitrogen metabolism	S.A.B., Apr. 12–13	.540	.014	11.14	4.85	.13
	Apr. 13–14	.529	.012	11.65	4.54	.10
	Apr. 18–19	.497	.011	12.72	3.91	.09
79	H.E.S., Oct. 13–14	.456	.004	8.11	5.62	.05
	Oct. 14–15	.528	.053	14.35	3.68	.37
80	C.R.Y., Oct. 27–28	.560	.000	7.78	7.20	.00
	Oct. 28–29	.572	.045	9.95	5.75	.45
81	A.H.M., Nov. 21–22	.456	.013	9.11	5.01	.14
	Nov. 22–23	.505	.041	13.05	3.87	.31
82	H.C.K., Nov. 24–25	.642	.027	9.38	6.84	.29
	Nov. 25–26	.668	.021	14.36	4.65	.15
83	H.R.D., Dec. 5– 6	.490	.032	13.25	3.70	.24
	Dec. 6– 7	.507	.075	13.53	3.75	.55
85	N.M.P., Dec. 9–10	[1] .574	[1] .006	[2] 11.05	5.20	.05
	Dec. 10–11	.634	.052	11.35	5.59	.46
	1906.					
89	D.W., Jan. 10–11	.778	.020	9.99	7.79	.20
	Jan. 11–12	.732	.014	14.46	5.06	.10

[1] Does not include possible amount in urine lost.
[2] Does not include nitrogen determined in urine lost.

On comparing the excretion of creatinine during the first 12 hours of the day with the total nitrogen (see table 198) it is seen that while in experiment No. 75 on the average 57.7 per cent of the total nitrogen for 24 hours is excreted between 7 a. m. and 7 p. m., but 51.6 per cent of the preformed creatinine is excreted during the same period. Furthermore, while the proportion of nitrogen excreted during the first 12 hours of the day remains quite constant on all days of the fast, the proportion of creatinine has a distinct tendency to diminish as the fast progresses.

Proportions of creatine nitrogen and total creatinine nitrogen excreted.—The proportions of the total urinary nitrogen derived from creatinine nitrogen and creatine nitrogen are of interest. The amounts of total nitrogen, total creatine-nitrogen and of total creatinine-nitrogen, as well as the proportions, are given in table 205.

The absolute amounts of total creatinine-nitrogen vary from 0.294 gram to 0.778 gram. While these wide variations are noted with different individuals, with the same individuals the absolute amount is relatively constant. The nitrogen of creatine is inappreciable save on the later days of the longer fasts, the highest amount observed being on the sixth day of experiment No. 75, 0.188 gram. The relative constancy in the creatinine-nitrogen from day to day is not accompanied by a similar constancy in the total nitrogen excretion, hence the proportion of creatinine-nitrogen in total nitrogen varies somewhat. In experiment No. 75, there is a distinct tendency for the proportion of creatinine-nitrogen to increase as the fast progresses, while in experiment No. 77 the reverse is true. An inspection of the figures shows that in almost every instance the variation is due to the fluctuations in the total nitrogen of the urine rather than to the nitrogen of creatinine.

The proportion of creatine nitrogen in the total nitrogen is exceedingly small on all save the later days of fast. The highest per cent observed was 1.75 on the sixth day of experiment No. 75. It is highly probable that errors in determination may account for the minute quantities of creatine found on the first day of fasting.

Relation of total creatinine excreted to body-weight.—As Folin has pointed out, the total creatinine excretion is relatively unaffected by the total nitrogen excretion when creatinine-free diets are consumed. The total creatinine elimination does vary, however, according to the individual, and in general, with body-weight. With persons of the same body-weight, nevertheless, marked differences in the proportion of body fat, and height, may result in marked variations in the amount of creatinine excreted per kilo of body-weight. For purposes of comparison, the data regarding the body-weight and the total creatinine, as well as the total creatinine per kilo of body-weight, are given in table 206.

The average total creatinine excreted per kilo of body-weight is 23.2 mg. The lowest observed amount was 17.6 mg. in experiment No. 74 and the highest 27.8 mg., during a 1-day observation in the first nitrogen metabolism experiment.

TABLE 206.—*Total creatinine excreted per day in urine per kilogram of body-weight in metabolism experiments with and without food.*

Experiment number.	Subject and duration of experiment.	(a) Body-weight.[1]	(b) Total creatinine (including creatine).	(c) Total creatinine per kilogram of body-weight ($b \div a$).
		Kilos.	*Grams.*	*Mgms.*
73	S.A.B., Jan. 28 to Feb. 2, 1905	57.1	1.044	18.3
74	S.A.B., Feb. 2 to 5, 1905	55.4	.977	17.6
75	S.A.B., Mar. 4 to 11, 1905	57.7	1.295	22.5
76	S.A.B., Mar. 11 to 14, 1905	[2] 55.7	[3] 1.411	[3] 25.3
1 Nitrogen metabolism	S.A.B., Mar. 14 to 23, 1905	[4] 56.3	[5] 1.566	[5] 27.8
77	S.A.B., Apr. 8 to 12, 1905	59.5	1.364	22.9
2 Nitrogen		[6] 57.7	[7] 1.435	[7] 24.9
metabolism	S.A.B., Apr. 12 to 19, 1905	[8] 60.1	[9] 1.334	[9] 22.2
79	H.E.S., Oct. 13 to 15, 1905	56.0	1.322	23.6
80	C.R.Y., Oct. 27 to 29, 1905	67.5	1.522	22.5
81	A.H.M., Nov. 21 to 23, 1905	60.9	1.292	21.2
82	H.C.K., Nov. 24 to 26, 1905	70.4	1.761	25.0
83	H.R.D., Dec. 5 to 7, 1905	54.9	1.340	24.4
85	N.M.P., Dec. 9 to 11, 1905	66.5	1.623	24.4
89	D.W., Jan. 10 to 12, 1906	77.8	2.029	26.1

[1] Average of weight at beginning and end of experiment.
[2] Average of weighings of first day.
[3] Amount for first day.
[4] Weight at 7 a. m., March 14.
[5] Amount for first day.
[6] Average weight for first two days. One kg. assumed as weight of clothing other than underclothes, and deducted from weighing of April 14.
[7] Amount for first two days.
[8] Average weight of April 18-19 less 1 kg. assumed for clothing other than underclothes.
[9] Amount for April 18-19.

In comparing different experiments on the same subject, as, for example, experiments Nos. 73-77 and the two nitrogen metabolism experiments, it is to be noted that in some of them the observations were confined to one day. Aside from the results obtained in experiments Nos. 73 and 74, the uniformity, not only with the same individual in the different experiments, but likewise with different individuals, is very striking. The results here obtained are wholly in accord with those observed by Folin,[67] Closson,[68] Klercker,[69] and Van Hoogenhuyze & Verploegh (11) in normal individuals.

In discussing the results of the determinations of creatine and creatinine in the urine of fasting men by the Folin method, the possibility of the presence of other bodies in the urine giving color reactions with sodium picrate must be

[67] Amer. Journ. Physiol. (1905), 13, p. 85.
[68] Amer. Journ. Physiol. (1906), 16, p. 252.
[69] Beiträge zur chem. Physiol. u. Path. (1906), 8, p. 59.

considered. As was pointed out by Jaffé,[70] acetone gives the same color with sodium picrate that creatinine produces. Folin[71] found that acet-acetic acid, acet-acetic ether, and hydrogen sulphide also give the reaction, but, as he points out, these constituents are all pathological and can easily be removed from urine. With the urine from fasting men, the researches of Brugsch (12), especially, have shown the presence of β oxybutyric acid as a constant constituent as well as amino acids and acetone. Kuelz[72] showed that even after 3 or 4 days of fasting in the case of insane patients, β oxybutyric acid was present. The influence of these acids on the Jaffé reaction has not to our knowledge been studied. Since unquestionably acetone[73] is formed in the urine of fasting man, it is at least possible that constituents other than creatinine may produce the color with sodium picrate.

No precautions were employed to remove these abnormal constituents of the urine, but during the heating with hydrochloric acid the acetone would in large part be expelled.

It is possible to conceive of an increased production of compounds giving a color with sodium picrate as the fast progresses, and thus, in part at least, account for the apparently constant elimination of total creatinine. On the other hand, it is hardly probable that the production of other color-producing materials should proceed at such a rate as to exactly compensate for any possible falling off in the production of creatinine, and hence while the results must be accepted with some reserve, it would appear that during fasting, the output of total creatinine remains constant, while the relative proportion between preformed creatinine and creatine indicates a constant change, the proportion of creatine increasing as the fast progresses.

Since this report was written evidence regarding the presence of creatine in pathological urine has been collected which would tend to sustain the alternate explanation of the presence of creatine given in a subsequent section of this report. (See p. 458.)

URIC ACID.

Unfortunately, the excretion of uric acid in fasting man has been only imperfectly studied, and in the experiments here reported but few observations were made. In some of the samples of the urine sent to New Haven for determination of creatinine, Professor Mendel kindly made determinations of the uric acid. It was found impracticable to carry out these determinations in the subsequent experiments with the limited amount of urine at our disposal.

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[70] Zeit. f. physiol. Chemie (1886), 10, p. 399.
[71] Zeit. f. physiol. Chemie (1904), 41, p. 224.
[72] Zeitschrift f. Biologie (1887), 23, p. 338.
[73] E. & O. Freund also report acetone and acet-acetic acid in Succi's urine during the Vienna fast.

The earliest records of the determination of uric acid in the urine of fasting man with which we are familiar are those of Ranke.[74] In three 24-hour fasts he found 0.236, 0.033, and 0.24 gram of uric acid, respectively. The author makes no comment on the unusually small amount obtained in the second experiment.

Pettenkofer and Voit[75] determined the uric acid in a 24-hour fast. The authors report that the subject excreted 0.5584 gram of uric acid. Unquestionably this excretion was somewhat augmented by the considerable quantities of beef extract that were consumed.

Uric acid was not determined by Luciani (4) in the experiments on Succi.

Monaco[76] determined the uric acid in a 20-day fast made by Succi. Using the Salkowski method he obtained on the last day with food 0.8228 gram of uric acid, and on the eighteenth and twentieth days of the fast 0.2565 and 0.244 gram, respectively. On the second day after the fast the uric acid amounted to 0.5539 gram. According to the author the relation between the total nitrogen and uric acid did not appear constant.

In the two fasting experiments reported by Sadovyen (2) uric acid was determined. In the first experiment, which lasted 2 days, and during which no water was consumed, the subject excreted 0.301 gram of uric acid in 24 hours. On the second day 0.291 gram was excreted. In a subsequent 4-day fasting experiment, the uric acid excretion was 0.412, 0.201, 0.301, and 0.357 gram, respectively.

The most elaborate series of observations recording the excretion of uric acid in fasting man is that of E. & O. Freund (10). The uric acid-nitrogen was determined on nearly every day of the 21-day fast. The largest amount recorded was on the first day, 0.29 gram (0.87 gram uric acid), and the smallest amount on the twenty-first day, 0.046 gram (0.138 gram uric acid). The quantity of uric acid-nitrogen gradually diminished as the fast progressed, although but little change occurred after the fifth day.

Brugsch (12) reports only the total purin-nitrogen, no attempt being made to isolate the nitrogen of uric acid. For the last 7 days of the 30-day fast, the total purin-nitrogen varied from 0.104 gram to 0.146 gram.

Schreiber & Waldvogel[77] observed the uric acid output of two individuals each of whom fasted 3 days. The uric acid excretion for the 3 successive days was 0.290, 0.233, and 0.197 gram with one subject, and 0.718, 0.405, and 0.205 gram with the second subject. R. Orgler[78] reports that during a 1-day fast he excreted 0.480 gram of uric acid.

[74] Arch. Anat. u. Physiol. (1862), p. 340.
[75] Zeitschr. f. Biol. (1866), 2, p. 479.
[76] Bull. della Soc. Lancis degli ospedali d. Roma (1894), xiv, 2, p. 102. Abstracted in Schmidt's Jahrbücher, 252, p. 109.
[77] Archiv f. experimentelle Path. u. Pharm. (1899), 42, p. 69.
[78] Allg. med. Ctrl.-Zeitung, 1896, No. 66. Cited by Magnus-Levy, Physiologie des Stoffwechsels (1905), p. 134.

The quantities of uric acid observed in the fasting experiments here reported are unusually small. For the five days of fasting experiment No. 73, the quantities of uric acid per day were 0.172, 0.122, 0.082, 0.059, and 0.054 gram, respectively. It is to be noted, however, that on the last 3 days of the fast, the quantities of sample available for the uric acid determinations were so small as to render the results reasonable estimates rather than accurate determinations. The fact remains, however, that remarkably small amounts of uric acid were excreted by this subject on the last 3 days of the fast. With the resumption of the ingestion of food, which was of a purin-free nature, i. e., milk, the uric acid excretion increased. On the 3 days of experiment No. 74, in which the subject remained inside the chamber, the uric acid excretion was 0.329, 0.537, and 0.407 gram, respectively. On the first day after the subject left the respiration chamber, when he partook of an elaborate diet of varied nature, the uric acid excretion increased to 0.744 gram.

In the absence of more complete data, little can be said regarding the uric acid excretion in the fasting experiments here reported, save that the evidence seems to indicate that remarkably small amounts of uric acid are excreted by fasting man after the first one or two days of the fast. This observation agrees in general with that of E. & O. Freund (**10**) save that the estimated amounts excreted by S. A. B. are considerably less than the quantities for the corresponding fasting days observed on Succi in the Vienna fast. The unusually low uric acid excretion observed in one day fasts by Ranke[79] likewise indicates that during even a short period of inanition the uric acid output may be greatly reduced.

PATHOLOGICAL CONSTITUENTS OF THE URINE.

Of the ordinary pathological constituents in urine (albumen and sugar) albumen has not been found in any of the long fasts made by Succi, and in but one, E. & O. Freund (**10**), was sugar present. The observations of Brugsch (**12**) on acidosis showed the presence of β oxybutyric acid.

Careful tests of all the samples of urine of the experiments here reported showed in no instance the presence of albumen or sugar. The large increase of carbon in the urine in experiment No. 77, may, as has been before stated, have been caused by the formation of β oxybutyric acid, although no direct evidence of its presence was obtained.

SULPHUR.

Sulphur in the urine is derived almost wholly from the oxidation of the sulphur in the protein molecule, for a very small amount of preformed sulphuric acid is taken with the food or drink. Consequently, as an index of protein katabolism, the total elimination of sulphur in the urine may be of value.

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[79] Loc. cit.

Sulphur occurs in the urine in at least three different forms: First, preformed sulphuric acid; second, oxidized sulphur which is combined with some organic radical to form the so-called ethereal sulphates; and third, the unoxidized or "neutral" sulphur. Not only did some of the earlier investigators fail to recognize clearly the different forms of sulphur or their significance, but in the records of the determinations which have been made there has been more or less lack of uniformity in the method of expressing the results. Some authors have expressed their data as S, others as H_2SO_4 and still others as SO_3. Since but little is known of the nature of the neutral sulphur, it seems most logical to record the total sulphur elimination as S, rather than H_2SO_4 or SO_3, and in subsequent reports it will be so expressed.

In consideration of the fact that much of the earlier work is here presented, and that physiological chemists have not been accustomed to interpret the results of sulphur determinations in terms of sulphur, in all the experiments here reported the old usage is retained. To pave the way for the subsequent expression of the results of analyses in terms of sulphur, the averages for the different days of the experiment are given in heavy faced type in tables 208, 210, and 211 as sulphur (S) along with the results expressed as sulphur trioxide (SO_3).

From a careful computation of the results as presented, the data for earlier fasting experiments (all calculated on the same basis, namely, SO_3, for purposes of comparison) are given in table 207 herewith. Unfortunately the determinations on Succi in Florence and Naples did not include the total sulphur, hence there are no data for these fasts regarding the neutral sulphur. E. & O. Freund (10) reported the total, the inorganic, the ethereal, and the neutral sulphur.

The results reported by Sadovyen (2) did not include the neutral sulphur and hence are comparable to the results in other experiments in which the inorganic and ethereal alone were determined.

It has recently been pointed out by Folin[*] that the determination of sulphuric acid as barium sulphate involves technicalities that have in many instances been overlooked. Hence the comparison of the results obtained by different investigators by the determination of sulphuric acid in the urine is somewhat questionable. In fact, it is tolerably clear that much of the older work involves errors which render even the determinations of total sulphur unreliable. Moreover, any errors in the determinations of either total sulphur or ethereal sulphates affect the measure of the neutral sulphur, since the latter is determined indirectly as the difference between the total sulphur and the ethereal (and inorganic) sulphates.

So far as the inorganic and ethereal sulphur is determined, it is probable that with certain limitations the results may, in general, be compared.

[*] Journal of Biological Chemistry, 1906, 1, p. 131.

Total sulphur.—The excretion of total sulphur expressed as SO_3 in the fasting experiments here reported is given in table 208. The averages, expressed as S and SO_3, are both included in the table.

At the time these determinations were made Folin's critical discussion of the method of determining sulphur had not appeared and hence these determinations are probably subject to all the errors there pointed out. Nevertheless, they represent a determination as accurate as most of the earlier work, and also, in all probability, give results that are comparable so far as the different days of the same experiment are concerned.

TABLE 207.—*Amounts of sulphur (as SO_3) eliminated in urine daily by fasting subjects.*

Day of fast.	Succi.					Cetti.			Breithaupt.			J.[1]
			At Vienna.									
	(a) At Florence.	(b) At Naples.	(c) Total.	(d) Inorganic and ethereal.	(e) Neutral (c−d).	(f) Total.	(g) Inorganic and ethereal.	(h) Neutral (f−g).	(i) Total.	(j) Inorganic and ethereal.	(k) Neutral (i−j).	(l)
Last food	*Gms.*[2]	*Gms.*[3]	*Gms.*	*Gms.*	*Gms.*	*Gms.*[4]	*Gms.*[5]	*Gms.*[4]	*Gms.*[4]	*Gms.*[5]	*Gms.*[6]	*Gms.*[2]
day....	....	2.59	....	....	....	....	2.429	....	2.352	2.331	0.021	....
1......	1.873	1.91	3.2	2.86	0.34	2.472	1.760	0.712	1.853	2.086[7]	....	1.925
2......	1.795	1.20	1.47	1.12	.35	....	1.486	....	1.955	1.744	.211	.501
3......	1.868	1.79	1.3	.983	.34	2.310	1.583	.727	2.447	2.050	.397	.851
4......	1.782	1.51	1.6	.917	.68	....	1.642	....	1.796	1.851[7]	....	.801
5......	1.709	1.46	....	....	....	1.774	1.492	.282	1.551	1.684[7]	....	....
6......	1.481	.99	1.4	.782	.618	....	1.422	....	1.481	1.438	.043	....
7......	1.371	1.22	1.4	.744	.656	1.950	1.305	.645	....	....	....	....
8......	1.222	1.19	1.16	[8].72	....	....	1.292	....	....	....	....	....
9......	1.069	1.10	....	....	....	2.075	[9]1.185	.890	....	....	....	....
10......	1.042	1.44	....	.615	....	1.546	1.181	.365	....	....	....	....

[1] Reported by A. Sadovyen (2).
[2] Probably inorganic and ethereal. Given by the investigator as H_2SO_4, but converted to SO_3 for purposes of comparison.
[3] Probably inorganic and ethereal.
[4] Given by the investigator as sulphur, but converted to SO_3 for purposes of comparison.
[5] Given by the investigator as H_2SO_4, but converted to SO_3 for purposes of comparison.
[6] Calculated by difference from the total and inorganic and ethereal SO_3.
[7] Discrepancies in the figures for total and inorganic and ethereal SO_3 makes calculation of neutral SO_3 impossible.
[8] Probably does not include ethereal sulphur.
[9] Calculated by difference from the total and neutral SO_3. The figure obtained by converting the H_2SO_4 as originally reported to SO_3 is 0.983 gram.

The total excretion of sulphur trioxide on the first day of these fasts ranges from 0.969 gram to 2.173 grams, averaging for the 12 experiments 1.468 grams. On the second fasting day, the variations are from 1.506 to 2.148 grams, and the average is 1.806 grams. In all but two cases, experiments Nos. 83 and 85, there was a distinct increase in the amount on the second day over the first.

Of the 5 experiments, which lasted 3 days or more, the excretion for the third day was lowest in No. 77, i. e., 1.709 grams, and highest in No. 69, 2.089 grams. The average for the 5 experiments was 1.867 grams, which indicates on the whole a still greater increase in the output as the fasts progressed. In fact, in all of the 5 experiments which lasted 3 days and over, the excretion was higher on the third than on the second day.

TABLE 208.—*Total sulphur (as SO_3) excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
69....	A.L.L., Dec. 16–19, 1904..	1.374	1.844	2.089	1.971	....	....	....
71....	S.A.B., Jan. 7–10, 1905..	1.298	1.775	1.893	1.671	....	....	....
73....	S.A.B., Jan. 28–Feb. 1, 1905	1.608	1.747	1.774	1.729	1.765	....	....
75....	S.A.B., Mar. 4–10, 1905..	1.559	1.669	1.871	1.802	1.668	1.648	1.553
77....	S.A.B., Apr. 8–11, 1905..	1.190	1.628	1.709	1.651	....	....	....
79....	H.E.S., Oct. 13–14, 1905..	1.355	1.940	....	....	....	....	....
80....	C.R.Y., Oct. 27–28, 1905..	.969	1.710	....	....	....	....	....
81....	A.H.M., Nov. 21–22, 1905..	1.427	2.036	....	....	....	....	....
82....	H.C.K., Nov. 24–25, 1905..	1.423	1.915	....	....	....	....	....
83....	H.R.D., Dec. 5–6, 1905..	2.173	1.755	....	....	....	....	....
85....	N.M.P., Dec. 9–10, 1905..	[1] 1.507	1.506	....	....	....	....	....
89....	D.W., Jan. 10–11, 1906..	1.730	2.148	....	....	....	....	....
	Average........ SO_3	1.468	1.806	1.867	1.765	1.717	1.648	1.553
	Average........ S	.588	.723	.748	.707	.688	.660	.622

[1] Does not include possible amount in urine lost.

There were 5 experiments in which the fast continued for 4 days or more. The output ranges from 1.651 grams in experiment No. 77 to 1.971 grams in experiment No. 69. In every instance there was a decrease from the amount excreted on the third day.

Observations regarding the fifth day of the fast are found in but 2 experiments, Nos. 73 and 75. In No. 73, the excretion was 1.765 grams, a slight increase over the fourth day, while in experiment No. 75, the excretion was somewhat less than on the fourth day, i. e., 1.668 grams.

The sulphur trioxide excretion for the sixth and seventh days of experiment No. 75 showed a slight but persistent decrease. It is interesting to note that the excretion on the seventh day was almost identical with the excretion of the first day of experiment No. 75.

Considering, then, the results as obtained from these experiments, it is seen that the excretion of sulphur increases on the second day. There is an increase on the third day and a steady diminution on the succeeding days of the fast.

Ratio of nitrogen to total sulphur.—Since practically all the sulphur in the urine results from the katabolism of protein, a parallelism in the excretion of

nitrogen and sulphur is to be expected. Indeed, it has long been urged that the sulphur excretion is as true a measure of protein katabolism as is the nitrogen excretion. In the fasting experiments with Cetti and Breithaupt, Munk (7) computed the ratios between the nitrogen and sulphur N/S. These ratios are given herewith.

Day.	1	2	3	4	5	6	7	8	9	10
Cetti	13.7	..	14.2	..	15	...	14	16	..	15.3
Breithaupt	13.5	13	13.5	17	17	16.6	..	..	..	...

The average ratio for the 6 days on which it was determined for Cetti was 14.7 and the average of 6 fasting days for Breithaupt was 15.1. In general, the quotients remained fairly constant, although there is a minimum of 13 and a maximum of 17 observed in the case of Breithaupt.

Commenting on the ratios obtained by Pellizzari & Luciani (4, p. 145), Munk shows that the Italian authors determined only the inorganic and ethereal sulphur and hence their values for total sulphur are somewhat too low.

It should also be said, however, that the values for nitrogen are likewise too low,[a] and hence the discrepancies tend to compensate. The ratios found in the Florence fast of Succi range during the first 10 days of fasting from 19.5 on the first to 16.2 on the tenth day.

TABLE 209.—*Ratio of nitrogen to total sulphur (S) in metabolism experiments without food.*

Experiment number.	Subject and date.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
69....	A.L.L., Dec. 16-19, 1904..	18.33	19.31	17.97	16.43	....	....	....
71....	S.A.B., Jan. 7-10, 1905..	11.25	15.53	17.27	16.04	....	....	....
73....	S.A.B., Jan.28-Feb. 1, 1905	15.97	17.10	16.20	14.99	14.12	....	....
75....	S.A.B., Mar. 4-10, 1905..	19.59	18.62	17.38	16.11	16.26	16.27	16.28
77....	S.A.B., Apr. 8-11, 1905..	18.49	16.53	16.03	17.30	....	....	....
79....	H.E.S., Oct. 13-14, 1905..	14.94	18.47	....	....	....	....	....
80....	C.R.Y., Oct. 27-28, 1905..	20.03	14.52	....	....	....	....	....
81....	A.H.M., Nov. 21-22, 1905..	15.94	15.96	....	....	....	....	....
82....	H.C.K., Nov. 24-25, 1905..	16.45	18.71	....	....	....	....	....
83....	H.R.D., Dec. 5- 6, 1905..	15.22	19.24	....	....	....	....	....
85....	N.M.P., Dec. 9-10, 1905..	18.84	18.81	....	....	....	....	....
89....	D.W., Jan. 10-11, 1906..	14.41	16.80	....	....	....	....	....
	Average..............	16.62	17.47	16.97	16.17	15.19	16.27	16.28

Luciani discusses at considerable length the fluctuations in this ratio, but in the light of our present knowledge of sulphur determinations, his discussion is at best inconclusive.

The ratios of nitrogen to total sulphur for the Middletown experiments have been computed and are given in table 209.

[a] See discussion by Munk (7), p. 118.

The ratio is highest for the first day of experiment No. 80, 20.03, and lowest for the first day of experiment No. 71, 11.25. The average ratios for all of the experiments remain relatively constant throughout the fasts. It is evident, however, that marked variation may occur in the experiments, even in those with the same subject. For example, in experiment No. 71 the ratios ranged from 11.25 on the first day to 17.27 on the third. It will be remembered that on the first day of this experiment an unusually small amount of nitrogen was excreted and hence the numerator of the fraction is small. Evidently, then, the low excretion of nitrogen was not accompanied by a correspondingly low excretion of sulphur. The average ratio for all of the experiments is 16.78. Further discussion of the significance of this ratio is deferred pending the consideration of the quantities of protein, fats, and carbohydrate katabolized during fasting.

Ethereal sulphates.—The work of Baumann,[*] on ethereal sulphates in the urine has led to the almost general acceptance of his views on the use of the amount of ethereal sulphates as an index of bacterial decomposition in the intestine. This view has been recently opposed by Folin,[*] who implies that the ethereal sulphates have a much more complicated origin than bacterial action.

The ethereal sulphur was not determined in the fasting experiments here reported, but in some of the earlier fasts, especially those with Cetti and Breithaupt, the amounts of ethereal sulphates were found.

An inspection of the data presented by Munk & Mueller (7) shows that the amount of ethereal sulphates is considerable on all the days of the fast. In one instance, namely, on the ninth day of Cetti's fast, the amount of the ethereal sulphate was nearly one-third of the total sulphuric acid. These writers point out that the amounts they found with Cetti and Breithaupt are ten times greater than those found by Luciani (4) in Succi's Florence fast.

The results of Munk & Mueller (7), viewed from the standpoint of Baumann, indicate a bacterial decomposition continuing throughout the fast and, indeed, in very considerable measure. On the other hand, in the observations of E. & O. Freund (10) on Succi during the Vienna fast, the amounts of ethereal sulphates (expressed as SO_3), range from 0.20 gram on the first fasting day to 0.058 gram on the twentieth fasting day, there being a gradual decrease as the fast progressed. These quantities are similar to those found by Luciani in the Florence fast, and, viewed from the standpoint of Baumann, indicate a very much lower degree of bacterial fermentation than do the results of Munk & Mueller on the Berlin fasters.

Inorganic and ethereal sulphates.—Although the data for computing the ethereal sulphates are lacking in the experiments here reported, the sum of the inorganic and ethereal sulphates has been recorded for all experiments in

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[*] Zeit. f. physiol. Chemie (1879), 3, p. 156.
[*] Amer. Journ. Physiol. (1905), 13, p. 97.

table 210. These data may be compared to the inorganic and ethereal sulphates of the earlier writers (see table 207). Except in the Vienna fast of Succi reported by E. & O. Freund (10) and Sadovyen's experiment (2) the amount of inorganic and ethereal sulphates (SO_3) is not far from 1.5 grams per day in all fasting experiments.

TABLE 210.—*Proportions of total sulphur (SO_3) excreted as inorganic and ethereal and as neutral sulphur in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.				
		Total.	Inorganic and ethereal.	Neutral.	In per cent of total.	
					Inorganic and ethereal.	Neutral.
		Grams.	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*
75.....	S.A.B., Mar. 4 to 10, 1905.....	1.559	1.354	0.205	86.8	13.2
77.....	S.A.B., Apr. 8 to 11, 1905.....	1.190	.934	.256	78.5	21.5
79.....	H.E.S., Oct. 13 to 14, 1905.....	1.355	1.162	.193	85.7	14.3
80.....	C.R.Y., Oct. 27 to 28, 1905.....	.969	.827	.142	85.3	14.7
81.....	A.H.M., Nov. 21 to 22, 1905.....	1.427	1.295	.132	90.8	9.2
82.....	H.C.K., Nov. 24 to 25, 1905.....	1.423	1.230	.193	86.4	13.6
83.....	H.R.D., Dec. 5 to 6, 1905.....	2.173	1.961	.212	90.2	9.8
85.....	N.M.P., Dec. 9 to 10, 1905.....	[1] 1.507	[1] 1.219	[1] .288	80.9	19.1
89.....	D.W., Jan. 10 to 11, 1906.....	1.730	1.472	.258	85.1	14.9
	Average.............. $\left\{\begin{matrix} SO_3 \\ S \end{matrix}\right.$	1.482 .593	1.273 .510	0.209 .083	85.9	14.1
Experiment number.	Subject and duration of experiment.	Second day.				
		Total.	Inorganic and ethereal.	Neutral.	In per cent of total.	
					Inorganic and ethereal.	Neutral.
		Grams.	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*
75.....	S.A.B., Mar. 4 to 10, 1905.....	1.669	1.480	0.189	88.7	11.3
77.....	S.A.B., Apr. 8 to 11, 1905.....	1.628	1.322	.306	81.2	18.8
79.....	H.E.S., Oct. 13 to 14, 1905.....	1.940	1.701	.239	87.7	12.3
80.....	C.R.Y., Oct. 27 to 28, 1905.....	1.710	1.483	.227	86.7	13.3
81.....	A.H.M., Nov. 21 to 22, 1905.....	2.036	1.891	.145	92.9	7.1
82.....	H.C.K., Nov. 24 to 25, 1905....	1.915	1.746	.169	91.2	8.8
83.....	H.R.D., Dec. 5 to 6, 1905.....	1.755	1.580	.175	90.0	10.0
85.....	N.M.P., Dec. 9 to 10, 1905.....	1.506	1.331	.175	88.4	11.6
89.....	D.W., Jan. 10 to 11, 1906.....	2.148	1.831	.317	85.2	14.8
	Average.............. $\left\{\begin{matrix} SO_3 \\ S \end{matrix}\right.$	1.812 .726	1.596 .639	0.216 .087	88.1	11.9

[1] Does not include possible amount in urine lost.

Neutral sulphur.—It is greatly to be regretted that the nature of neutral sulphur in fasting urines has not been more definitely studied. The differential method of obtaining neutral sulphur presumes so great an accuracy that it is

difficult to interpret the results obtained on Succi, Cetti, and Breithaupt with any degree of satisfaction. Indeed in the experiments on Breithaupt, in at least three instances, the amount of inorganic and ethereal sulphur was greater than the total sulphur and it is fair to assume that the determinations on the Berlin fasters were made as accurately as any up to that date. The more recent determinations of E. & O. Freund (10) on Succi are probably less open to objection, although the methods employed are not given and hence the accuracy of the results is uncertain. Furthermore, in the fasts of Succi at least, various amounts of alkaline waters were consumed. Presumably these contained but small amounts of preformed sulphates, although at times aperient water (Janos) was taken. The data obtained in the earlier experiments regarding the excretion of neutral sulphur are, therefore, extremely unsatisfactory.

In connection with some of the experiments here reported, the amounts of neutral sulphur were determined. The data are recorded in tables 210 and 211. For convenience in computing, the "total" and "inorganic and ethereal" sulphur are also included in the first table, as are also the proportions of the total sulphur represented by the "inorganic and ethereal" and the neutral sulphur.

TABLE 211.—*Proportions of total sulphur (SO_3) excreted as inorganic and ethereal and as neutral sulphur in metabolism experiments without food.*

Day of experiment.	Experiment number.	Inorganic and ethereal.	Neutral.	
			Amount.	Proportion of total.
		Grams.	*Grams.*	*Per cent.*
Third day......	77........	1.484 **.594**	0.225 **.090**	13.2
Fourth day.....	75........	1.618	.184	10.2
	77........	1.425	.226	13.7
	Average ..	1.522 **.610**	.205 **.082**	11.9
Fifth day......	75........	1.520 **.609**	.148 **.059**	8.9
Sixth day......	75........	1.477 **.592**	.171 **.068**	10.4
Seventh day....	75........	1.414 **.566**	.139 **.056**	8.9

The neutral sulphur (SO_3) elimination on the first day of the fast varied from 0.132 to 0.288 gram, and the average for the 9 experiments was 0.209 gram. The proportion of total sulphur represented by the weight of neutral sulphur varied from 9.2 to 21.5, averaging for all experiments 14.1 per cent. On the second day of the fast, the weight of neutral sulphur in the urine ranged from 0.145 to 0.317, averaging 0.216 gram, while the proportion of total sulphur represented by the neutral sulphur varied from 7.1 to 18.8 per cent. The

average is 11.9 per cent. Unfortunately, the data for the third day were secured from only one experiment in which the neutral sulphur was 0.225 gram, or 13.2 per cent of the total sulphur eliminated. On the fourth day, the determinations made in two experiments gave 0.184 and 0.226 gram respectively. Expressed in per cents of total sulphur, these weights corresponded to 10.2 and 13.7 per cent. On the fifth, sixth, and seventh days, the neutral sulphur was determined in experiment No. 75 only. The amounts excreted were less than on previous days, being 0.148, 0.171, and 0.139 gram, respectively, these weights corresponding to 8.9, 10.4, and 8.9 per cents of the total sulphur. There is, then, a tendency for the actual weight of neutral sulphur to decrease as the experiment continues, and the per cent of total sulphur represented by the neutral sulphur likewise diminishes.

The effect of the bile flow on the neutral sulphur has generally been maintained, since it was believed that the taurin contributed in large measure to the amount of neutral sulphur found in the urine. Luciani (4) maintained that the secretion of bile continued throughout the 30 days of the Florence fast, since from time to time Succi vomited material stained with bile pigments. In common with all other secretions, however, the bile flow must be distinctly diminished and the results obtained in the Middletown experiments might be taken as indicating that there is a relationship between the bile flow and the amount of neutral sulphur, for, as has been pointed out above, not only the total but the relative amount of neutral sulphur persistently diminishes as the fast progresses. This conclusion is, however, distinctly at variance with that drawn from the recent experiments of Shaffer[64] on a woman with a biliary fistula.

Judged from the standpoint of Folin's theory of protein metabolism, the variations in the amounts of sulphur excreted indicate that there is scarcely any greater disintegration of tissue protein during fasting, than under normal conditions with food. That this view is in marked contrast to the many physical observations made on the size of the liver and other organs, as well as of the muscles, during fasts no longer than some of these recorded here, would lead to the belief that in these organs the actual structure is not necessarily materially drawn upon during fasting, but that the whole organism becomes deprived of its fluid to a considerable extent and hence diminishes in volume.

While in the paper presenting his views of protein metabolism Folin[65] maintained that there was a distinct relation between the neutral sulphur and the endogenous protein katabolism, it is of interest to note that in a subsequent statement[66] he says that his more recent researches would indicate some relationship between the food ingested and the neutral sulphur.

[64] Amer. Journ. Physiol. (1906), 17, p. 340.
[65] Amer. Journ. Physiol. (1905), 13, p. 117.
[66] Private communication reported by Shaffer, loc. cit., p. 375.

While in Folin's metabolism experiments there was a marked parallelism between the excretion of creatinine and neutral sulphur, in these experiments the total creatinine remains constant during the fast, and the neutral sulphur persistently decreases. The preformed creatinine on the other hand more nearly follows the neutral sulphur elimination.

The results here obtained during inanition serve to complicate the matter still further, and there is obviously much research to be done upon the problem of neutral sulphur before definite conclusions can be drawn.

PHOSPHORUS.

Under normal conditions, with food, material amounts of phosphorus are excreted in the feces as well as in the urine. In fasting experiments, however, and specifically in the experiments under discussion in this report, only the phosphorus excretion of the urine has been adequately studied. The difficulties experienced in the proper separation of fasting feces precludes any discussion of the amount of phosphorus excreted through the feces during fasting.

The phosphorus of the urine, under normal conditions when food is given, may originate from several sources: First, preformed phosphates of the food, such as the phosphates of milk; second, phosphorus of the nucleo-proteids of food; and third, phosphorus already stored in the body, including of course the calcium phosphate of the bones, which might possibly become disintegrated to a certain extent. In fasting urine, especially, this last factor should not be overlooked.

Determinations of phosphorus in urine were common in the earlier fasting experiments, and since the method, i. e., volumetric titration with uranium salts, has not been materially modified, the results are much more nearly comparable than is the case with almost any other element involved in katabolism. While there is not complete uniformity on the part of writers in expressing the results of phosphorus determinations, it has been common to express them in the form of phosphorus pentoxide (P_2O_5). For the reason set forth in the discussion of sulphur in the preceding section, it has been thought desirable to report the elimination of phosphorus expressed as the element in subsequent experiments. The daily amounts of phosphorus (as P_2O_5) eliminated in the urine of fasting subjects are presented in table 212. For subsequent discussion the ratios of nitrogen to phosphorus pentoxide (N/P_2O_5) are given in heavy-faced type in the same table.

The phosphorus pentoxide excretion is by no means uniform in the three experiments with Succi. For example, there were but 1.46 grams excreted on the fourth day of fasting in the Naples experiment, while there were 2.54 grams on the corresponding day of the fast in Vienna. On the whole, there was a much larger amount of phosphorus excreted per day at Vienna than during either of the two earlier fasts. In Cetti's experiment, the phosphorus excretion

was much larger than in any of the experiments with Succi, while Breithaupt, on the other hand, excreted phosphorus in about the same amounts as did Succi. The lowest phosphorus output is found in the case of the subject J.

Sohn eliminated extremely large amounts and, singularly enough, the excretion increased throughout the whole experiment.

TABLE 212.—*Ratio of nitrogen to phosphorus (P_2O_5) and amount of phosphorus (P_2O_5) eliminated daily in urine by fasting subjects.*

Day of fast.	Succi.			Cetti.	Breithaupt.	J.[1]	Sohn.	Subject I.[4]	Flora Tosca.	Keller.[5]
	At Florence.	At Naples.	At Vienna.							
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Last food day...	....	**4.73** 1.90	....	**4.89** 2.76	**4.84** 2.69	....	**6.21** 3.381	**4.53** 1.58	**5.24** 2.670	....
1......	**7.87** 1.930	**4.90** 1.78	**5.70** 2.98	**5.22** 2.597	**6.42** 1.56	**7.40** 1.682	**5.37** 2.308	**3.97** 2.22	**5.65** 1.550	**4.41** 1.86
2......	**5.91** 2.051	**4.64** 1.82	**4.07** 2.75	**4.30** 2.925	**5.25** 1.89	**5.20** 1.091	**5.45** 2.268	**3.81** 2.65	**4.58** 1.830	**3.55** 1.90
3......	**7.30** 2.090	**4.64** 1.95	**4.19** 2.52	**3.90** 3.289	**5.25** 2.53	**6.51** 1.491	**6.17** 2.270	**4.41** 2.65	**4.64** 2.654	**3.24** 2.44
4......	**6.64** 2.120	**5.83** 1.46	**4.25** 2.54	**4.17** 2.974	**5.42** 2.360	**6.63** 1.571	**5.54** [2] 5.052	....	**3.20** 2.934	**4.54** 2.58
5......	**5.90** 2.394	**3.74** 2.64	**4.40** 2.51	**3.73** 2.871	**5.00** 2.19	....	[3] .... [3]	....	**4.50** 1.749	....
6......	**5.18** 2.150	**3.49** 2.47	**4.85** 2.27	**3.79** 2.667	**4.32** 2.29	....	**4.43** 2.434	....	**7.23** 1.069	....
7......	**5.53** 1.865	**3.28** 2.32	**4.13** 2.13	**4.09** 2.663	....	....	**4.00** 3.150	....	**8.57** 0.718	....
8......	**5.85** 1.601	**4.18** 1.48	**4.22** 2.31	**5.17** 1.722	....	....	**4.86** 4.442	....	**4.64** 1.658	....
9......	**6.29** 1.360	**4.63** 1.49	**4.19** 2.40	**5.24** 2.065	....	....	....	....	**4.32** 1.702	....
10......	**5.96** 1.246	**4.37** 1.23	**4.24** 1.68	**10.90** .948	....	....	....	....	**4.65** 1.461	....
Av. ratio $\frac{N}{P_2O_5}$ (for fasting days only)..	**6.24**	**4.37**	**4.43**	**4.97**	**5.28**	**6.29**	**5.20**	**4.06**	**5.14**	**3.94**

[1] Reported by A. Sadovyen (3).
[2] Amount for 2 days.
[3] See Note (2).
[4] Reported by Schreiber and Waldvogel; probably as P_2O_5.
[5] Reported by A. Keller, Zeit. f. physiol. Chemie (1900), 29, p. 165.

With the subject of Schreiber and Waldvogel, the excretion is not far from that of Sohn for the corresponding days of the fast. The more recent observations on the fasting girl, Flora Tosca, show a relatively large excretion of phosphoric acid, assuming that her body-weight (which unfortunately was not given) is lower than that of the other fasting subjects.

There is as a rule a tendency for the phosphoric acid excretion to increase for a few days after fasting begins and then subsequently to diminish. Some instances of an extremely low excretion are to be observed, namely, on the tenth

day of the fast of Cetti and on the seventh day of the fast of Flora Tosca. The amount of phosphorus pentoxide eliminated per day is, in general, not far from 2.2 grams.

The determinations of phosphorus in the Middletown experiments were made by two methods, as is shown in the detailed tables; one by titration with uranium salt, the other by fusion using the modified sodium peroxide method of Dubois.

Since the titrations were possibly less accurate than the gravimetric determinations, the latter only are included in table 213.

TABLE 213.—*Ratios of nitrogen to phosphorus (P_2O_5) and amounts of phosphorus*[1] *excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
69....	A.L.L., Dec. 16 to 19, 1904...	10.78 0.936	11.06 1.192	14.19 1.060	12.44 1.043	....	....	....
71....	S.A.B., Jan. 7 to 10, 1905...	7.93 .736	8.33 1.326	6.55 2.000	5.97 2.038	....	....	....
73....	S.A.B., Jan. 28 to Feb. 1, 1905	4.39 2.345	6.29 1.904	5.06 1.938	4.81 2.159	4.68 2.134	....	....
75....	S.A.B., Mar. 4 to 10, 1905...	8.55 1.431	5.52 2.255	6.34 2.055	4.83 2.406	5.23 2.078	5.19 2.071	4.87 2.081
77....	S.A.B., Apr. 8 to 11, 1905...	4.71 1.871	3.00 2.763	4.41 2.492	4.35 2.634	....	....	....
79....	H.E.S., Oct. 13 to 14, 1905...	7.50 1.081	8.62 1.664	....	....	....	....	....
80....	C.R.Y., Oct. 27 to 28, 1005...	6.57 1.184	4.11 2.421	....	....	....	....	....
81....	A.H.M., Nov. 21 to 22, 1905...	6.19 1.472	5.37 2.430	....	....	....	....	....
82....	H.C.K., Nov. 24 to 25, 1905...	8.43 1.113	7.18 2.000	....	....	....	....	....
83....	H.R.D., Dec. 5 to 6, 1905...	5.51 2.407	4.84 2.793	....	....	....	....	....
85....	N.M.P., Dec. 9 to 10, 1905...	8.79 [2]1.257	9.55 1.189	....	....	... .	....	....
89....	D.W., Jan. 10 to 11, 1905...	4.24 2.354	4.61 3.134	....	....	....	....	....
	Average...	6.97 1.516	6.69 2.089	[3]5.82 1.909	[3]4.82 2.056	4.96 2.106	5.19 2.071	4.87 2.081

[1] By fusion method.
[2] Does not include possible amount in urine lost.
[3] Omitting experiment No. 69.

The total weight of phosphorus (expressed as P_2O_5) excreted on the first day of the different fasts varied from 0.736 gram, in experiment No. 71, to 2.407 grams in experiment No. 83, averaging for the first day 1.516 grams. Even with the same subject (S. A. B.) in different experiments, the variations range from 0.736 to 2.345 grams. On the first day of the fast, therefore, there was apparently no uniformity in the excretion of phosphoric acid.

The variations on the second day are from 1.189 to 3.134 grams, the average for the 12 experiments being 2.089 grams. In general, there is a noticeable increase in the phosphoric acid elimination on the second day of the fasts, the only exceptions to this rule being in the case of experiments Nos. 73 and 85.

In the 5 fasts which lasted 3 days or more, the phosphoric acid excretion on the third day ranges from 1.06 to 2.492, averaging for all experiments 1.909 grams. Considering the experiments with S. A. B., there is an increase on the third day over the second day in the first two and a decrease in the last two, the average amount for the four experiments being practically the same on the third as on the second day.

In the experiments which lasted 4 days, the excretion on the fourth day varied from 1.043 to 2.634 grams. With the subject A. L. L., the phosphoric acid excretion practically reached a minimum, while with the subject S. A. B., there is a definite increase over the third day in all cases. The excretion on the fourth day of experiment No. 77 is not quite as large as on the second.

The data secured with S. A. B., for the fifth, sixth, and seventh days of fasting show that the phosphoric acid elimination remains practically constant at a little over 2 grams, a distinct falling off from the average maximum amount on the fourth day.

From the summary of the data given above it is evident that to draw conclusions concerning the relative phosphorus excretion during the successive days of fasting is most difficult, for even with the same subject there is no uniformity in the excretion. Thus, in considering the second, third, and fourth days of experiments Nos. 71 and 77, we find there was excreted 1.326, 2.000, and 2.038 grams in experiment No. 71, while in experiment No. 77, there was excreted during the same period 2.763, 2.492, and 2.634 grams.

Compared with the earlier experiments the results here obtained show on the whole a noticeably lower phosphorus elimination. The unusually low results obtained in experiment No. 69 can possibly be partially explained by the fact that in the feces of the 3 days with food (experiment No. 70) there was an abnormally high ash and a large per cent of calcium soap, thus indicating a marked disturbance of the ash metabolism. The results do not clearly show in just what manner the phosphorus metabolism was affected. Pending the determinations of the calcium and magnesium in the urine samples for these experiments,[a] but few definite conclusions can be drawn.

Organic phosphorus in urine.—The contention has been made by several writers[b] that varying amounts of phosphorus in organic combination exist in

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[a] It has thus far been impossible to complete these analyses as the determinations were taken up only recently. The results and a discussion of the data will be published later.

[b] Oertel, Zeit. f. physiol. Chemie (1898), **26**, p. 123; A. Keller, Zeit. f. physiol. Chemie (1900), **29**, p. 146; Bornstein, Archiv f. die ges. Physiol. (1904), **106**, p. 66; Symmers, Journ. Path. Bact. (1905), **10**, pp. 159 and 427.

urine, which are not determined by titration with uranium salts. On the other hand, LeClerc and Dubois [89] were unable to detect measurable amounts of such organic phosphorus.

In the Middletown experiments gravimetric determinations of phosphorus were made in the daily composite samples, while the determinations by titration with uranium acetate were made on the different periods as well as the composite samples for the day. Obviously, the sum of the amounts of phosphorus found in the different periods should agree with that found in the composite sample. The determinations made in this way serve two purposes—they give an idea as to the proportional distribution of the excretion of phosphorus over the 24 hours, and they furnish a check on the samples for the daily composite and the periods.

If the results obtained by the titration method are to be taken as representing the amount of phosphorus excreted in the urine of any given period, it is important that the absence of organic phosphorus in the urine be clearly proved as otherwise the results by titration have little value. Consequently, the composite sample for each day's urine was concentrated and ignited with sodium peroxide, and the phosphoric acid determined gravimetrically. The amount of phosphoric acid thus found in a total day's urine was compared with the amount found by titration, the results being recorded in the statistical tables along with the weight, composition, and heat of combustion of urine. An inspection of these tables shows that, in general, the amount of phosphoric acid as found by titration was a trifle larger, if anything, than that found by fusion, which is contrary to what would be expected if organic phosphorus was present. It might further be properly contended that the very fact that the titration method gives on the whole a larger amount of phosphorus than the fusion method is of itself evidence that the titration method as carried out in these experiments is not sufficiently accurate to detect the presence of the small amounts of organic phosphorus usually found. Furthermore, Keller, whose experiment on himself is of especial interest here since it was made on a fasting man (4 days), found amounts of organically combined phosphorus pentoxide amounting to 0.017, 0.0294, 0.0344, and 0.0573 gram, respectively. The increased organic phosphorus elimination as the fast progressed is, according to Keller, of especial significance in interpreting the rôle of organic phosphorus in metabolism.

In the light of the experience of Folin and LeClerc & Dubois, it seems hardly probable that any appreciable amounts of organic phosphorus occur in the urine, and at least in the experiments here reported, the titration with uranium acetate may be taken as a measure of the total phosphorus.

Periodic distribution of phosphorus.—By means of the simple titrations with uranium acetate, determinations of phosphorus in the samples of urine

[89] Journ. Amer. Chem. Soc. (1904), 26, p. 1112.

for the separate periods of the day were readily made. In the series of experiments, Nos. 73 to 76, inclusive, these determinations were carried out. The results are presented in table 214. For purposes of comparison, the experiments with food are also included. In comparing the results, it should be borne in mind that experiment No. 74 immediately followed experiment No. 73, and experiment No. 76 likewise followed immediately experiment No. 75.

TABLE 214.—*Periodic distribution of phosphorus*[1] *(as P_2O_5) in urine in metabolism experiments with and without food.*

Experiment number.	Subject and date.	7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	Total for first 12 hours.		Total for last 12 hours.		Total for 24 hours.
				Am't.	Proportion of total for 24 hours.	Am't.	Proportion of total for 24 hours.	
	Experiments without food.	*Grams.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Per ct.*	*Grams.*
73	S. A. B., Jan. 28 to 29, 1905	[2]....	[2]....	[2]....	....	[2]....	....	[3] ....
	Jan. 29 to 30, 1905	0.505	0.618	1.123	54.9	.923	45.1	2.046
	Jan. 30 to 31, 1905	.490	.508	.998	51.5	.940	48.5	1.938
	Jan. 31 to Feb. 1, 1905	.518	.690	1.207	63.5	.695	36.5	1.902
	Feb. 1 to 2, 1905	.575	.692	1.268	57.9	.920	42.1	2.188
	Total, 4 days	2.088	2.508	4.596	....	3.478	....	8.074
	Average per day	.522	.627	1.149	56.9	.870	43.1	2.018
75	S. A. B., Mar. 4 to 5, 1905	.383	.394	.778	53.6	.674	46.4	1.452
	Mar. 5 to 6, 1905	.591	.802	1.392	60.5	.909	39.5	2.301
	Mar. 6 to 7, 1905	.453	.635	1.088	51.7	1.016	48.3	2.104
	Mar. 7 to 8, 1905	.549	.798	1.347	55.7	....	44.3	[3] 2.416
	Mar. 8 to 9, 1905	.549	.665	1.214	55.4	.978	44.6	2.192
	Mar. 9 to 10, 1905	.561	.578	1.139	56.0	.896	44.0	2.035
	Mar. 10 to 11, 1905	.522	.618	1.141	58.1	....	41.9	[3] 1.963
	Total, 7 days	3.608	4.490	8.099	....	[4]4.473	....	14.463
	Average per day	.515	.641	1.157	56.0	[4].895	[5]44.0	2.066
	Experiments with food.							
74	S. A. B., Feb. 2 to 3, 1905	.461	.392	.853	61.3	.537	38.7	1.390
	Feb. 3 to 4, 1905	.315	.384	.699	60.9	....	39.1	[3] 1.148
	Feb. 4 to 5, 1905	.238	.308	.546	47.8	....	52.2	[3] 1.141
	Total, 3 days	1.014	1.084	2.098	....	[6].537	....	3.679
	Average per day	.338	.361	.699	57.0	.537	[5]43.0	1.226
76	S. A. B., Mar. 11 to 12, 1905	.375	.200	.575	70.0	.247	30.0	.822
	Mar. 12 to 13, 1905	.113	.109	.222	59.1	....	40.9	[3] .375
	Mar. 13 to 14, 1905	.053	.137	.190	24.1	.598	75.9	.789
	Total, 3 days	.541	.446	.987	....	[7].845	....	1.986
	Average per day	.180	.149	.329	49.7	.423	[5]50.3	.662

[1] Titration method.
[2] Not determined.
[3] Total in composite urine.
[4] For 5 days.
[5] Percentage by difference.
[6] For 1 day.
[7] For 2 days.

The proportion of the total phosphoric acid excreted in the first twelve hours is, on the average, not far from 57 per cent, although considerable differences, even in the fasting experiments, are found. For example, the variations in experiment No. 73 are from 51.5 to 63.5 per cent. In the food experiments, much larger variations appear, the most noticeable being that on the last day of experiment No. 76, where but 24.1 per cent of the total phosphoric acid was excreted during the period from 7 a. m. to 7 p. m.

Thus it is seen that, in general, the larger proportion of the phosphorus is excreted in the day period and, indeed, on reference to table 198, it will be noticed that the proportions thus excreted correspond very closely, in general, to the proportions of total nitrogen excreted during this period.

Ratio of nitrogen to phosphorus in the urine.—The disintegration of phosphorized material in the body during fasting presumably follows the general course of protein katabolism, save for the drafts upon the phosphatic material of the bones, and hence the ratio of nitrogen to phosphorus in the excretion, when compared with the ratio of nitrogen to phosphorus in the various tissues of the body is of interest. According to Munk (7, p. 159) there are about 6.8 [a] parts of nitrogen to each part of phosphorus pentoxide in flesh, and 6.4 parts of nitrogen to one of phosphorus pentoxide in the liver. Accordingly it is to be expected that, during fasting, the ratio of nitrogen to phosphorus pentoxide would be not far from 6.6. Ratios lower than this would indicate a draft upon phosphatic material of low nitrogen content such as bone.

In experiments with Succi, the ratios were computed by Luciani (4), but for the Florence fast in table 212, given above, the values for total nitrogen as corrected by Munk are used in computing the ratios. The ratio on the first day in the experiment at Florence is 7.87 and there is a general tendency for the ratios to diminish as the fast progresses. In the fast at Naples the ratio is more nearly constant, and the initial ratio, 4.90, is much lower than that of the Florence fast. The Vienna fast shows singularly constant ratios after the first day, the minimum being 4.07 (second fasting day) and the maximum 4.85 (sixth fasting day).

The excretion of so small an amount of phosphorus pentoxide on the tenth day of Cetti's fast resulted in a very high ratio (10.00). Aside from this day, the average ratio for the nine days of fasting is 4.4. In the other fasts the ratio is in practically all cases much below 6.6.

The peculiarity in the ratios for the sixth and seventh days of the fast of Flora Tosca may possibly be explained by the fact that on the sixth day the subject defecated after taking an aperient, while on the seventh she had considerable muscular exercise.

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[a] Forster, Zeit. f. Biol. (1873), 9, p. 363, and ibid. (1876), 12, p. 466, gives the relation between the total nitrogen and phosphoric anhydride in dog flesh as 7.2.

In the Middletown experiments, wide variations in these ratios are observed. For example, in experiment No. 69, the first in which the ratio could be obtained, it rose to 14.19 on the third day. The lowest ratio observed on any day was that on the second day of experiment No. 77, 3.90.

In experiment No. 69 there was an abnormally low phosphoric acid elimination, and hence the ratio is unusually high. In averaging all of the experiments, these high ratios have been taken into consideration only on the first two days. While they do not have a great influence in the averages of the first two days of the fast, since they are there averaged with 11 other experiments, on the third and fourth days, they would very materially raise the average value of the ratio. There is, as is to be expected, a slight tendency for the ratio to fall off as the fast progresses, yet the ratios are on the whole considerably higher than those found with the other fasting experiments given in table 212.[a] The ratio apparently is constant after the third day of fast.

While ratios as low as are commonly observed during a fast point to the probable disintegration of the bones, it is only in those experiments where the calcium and magnesium output has been determined that the complete data for this deduction are present. Unfortunately the quantitative determination of the earthy bases in the urine of the Middletown experiments have not as yet been made.

The ratios obtained by Brugsch (12) on the twenty-third to thirtieth days of fasting indicate that the draft upon the phosphorus of the skeleton may in prolonged fasting be very small. It is, moreover, still to be questioned whether data regarding the phosphorus excretion, even when supplemented by determinations of calcium and magnesium, will ever permit correct estimates of the apportionment of the phosphorus katabolism among skeleton, nucleins, and lecithins.[b]

CHLORINE.

The elimination of chlorine in feces is normally very small, and hence during inanition it can properly be said that all chlorine is eliminated through the urine. The chlorine excreted during fasting may arise from the previous food, the soluble chlorides of which are rapidly excreted, the excess of chlorides in the fluids of the body, and the chlorine "combined" with the flesh katabolized.[c]

Since muscle contains normally but 0.04 per cent chlorine, the amounts of protein usually katabolized during inanition can result in the liberation of but a small amount of chlorine.

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[a] Brugsch (12) found an average ratio of 5.9: 1 during the last 8 days of the 30-day fast made by Succi in Hamburg. This ratio is considerably higher than those found on the average for the third to seventh days of the Middletown fasts.
[b] Edlefsen, Deutsches Arch. f. klin. Medizin. (1881), 29, p. 409.
[c] Belli, Zeit. f. Biol. (1903), 45, p. 203.

The method of determining chlorine in the urine has undergone no marked modifications in a number of years past and hence the determinations made by different observers may be compared with reasonable accuracy.

While it has been the custom in many instances to report chlorine in terms of sodium chloride,[*] for purposes of comparison the determinations in the earlier fasts are here expressed in terms of chlorine. Only the first 10 days of each of the three fasts by Succi are here given.

TABLE 215.—*Amounts of chlorine eliminated in urine daily by fasting subjects.*

Day of fast.	Succi.			Cetti.	Breithaupt.	J.[1]	Sohn.	Flora Tosca.
	At Florence.	At Naples.	At Vienna.					
	Grams.	*Grams.*[3]	*Grams.*[4]	*Grams.*	*Grams.*	*Grams*	*Grams.*[4]	*Grams.*[2]
Last food day	[2]6.322	7.45	....	5.482	5.55	....	7.472	7.51
1	1.350	7.68	9.029	1.606	3.92	5.624	4.148	2.99
2	.539	4.72	3.212	2.308	1.1	5.011	2.341	1.73
3	1.155	3.30	1.551	1.7	.85	1.49	2.402	3.66
4	.848	.78	1.479	1.548	.75	2.01	[5]3.608	1.90
5	.817	.91	1.182	1.396	.44	....		.38
6	.840	.62	1.291	1.068	.35	....	1.518	.30
7	.800	.61	1.109	.95	....	....	1.466	.32
8	.736	.42	1.115	.814	....	....	1.997	1.15
9	.550	.73	1.212	1.104	....	....	....	1.32
10	.513	.77	.873	.62	....	....	....	1.07

[1] Reported by Sadovyen.
[2] Average of 6 days before fast began.
[3] Reported as "chlorides," not converted to chlorine.
[4] Given by the investigators as NaCl, but converted to chlorine for purposes of comparison.
[5] Amount for 2 days.

In the fast of Succi at Naples, the authors (6) express the chlorine as "chlorides." The extremely small amounts of chlorine excreted after the first four days of the fast, however, make it appear questionable whether the determinations are not actually on a basis of chlorine rather than chlorides. The results as given in the second column of table 215 are, however, transcribed directly from the records of Ajello and Solaro. Obviously, if these results are in terms of sodium chloride, the chlorine corresponding to these amounts would be considerably less and the chlorine excretion much lower than in any other experiment with which they are compared, save on the last two days of the experiment with Breithaupt and the fifth, sixth, and seventh days of the experiment with Flora Tosca.

[*] On the 3 single fasting days reported by Pettenkofer & Voit (Zeit. f. Biol. (1866), 2, p. 479), the sodium chloride in the urine amounted to 14.6, 13.2, and 8.56 grams, respectively. The determinations of sodium chloride in these experiments did not represent those during complete fasting since the subject consumed a considerable amount of salt in connection with a small amount of meat extract. Ranke (Archiv Anat. u. Physiol. (1862), p. 338) reports the sodium chloride excretion in two 24-hour fasting experiments as 11.0 and 5.3 grams, respectively.

The table above shows that the chlorine elimination on the last food day is invariably large and that on the first fasting day there is usually a marked diminution in the amount. On the first day of the Vienna fast, however, a very large quantity of chlorine, 9.029 grams, was excreted, while singularly enough, with the same subject, Succi, in the Florence fast, the smallest amount observed on the first day of any fast was recorded. In general, immediately after the first fasting day the chlorine output reaches a low level and there is a slight tendency for the amount to diminish as the fast progresses. No regularity, however, is observed in any of the experiments. Especially noticeable are the marked variations in the relative chlorine excretion in the three fasts of Succi. The amounts in the Vienna fasts are persistently higher than those in the Florence fast. Daiber* found Succi's urine almost chlorine-free on the twentieth day of the Zurich fast. It is, furthermore, to be noted that during Succi's fasts, he consumed at varying times different amounts of mineral water (Riolo) containing a considerable percentage of chlorine; thus, on the third, sixth, and seventh fasting days of the Florence fast, this mineral water was used. Luciani, in discussing these results, points out that after the first few days of fasting, the body has lost such considerable amounts of stored sodium chloride that the amounts absorbed from the mineral water are not immediately excreted but retained, and subsequently eliminated.

TABLE 216.—*Chlorine excreted in urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
73....	S.A.B., Jan. 28 to Feb. 1, 1905.	1.630	0.466	0.159	0.356	0.408	....	....
75....	S.A.B., Mar. 4 to 10, 1905....	1.447	1.338	.616	.245	[1]....	0.387	0.420
77....	S.A.B., Apr. 8 to 11, 1905....	5.294	1.671	1.919	.647	....	....	....
79....	H.E.S., Oct. 13 to 14, 1905....	2.917	3.622	....	....	....	....	....
80....	C.R.Y., Oct. 27 to 28, 1905....	8.898	4.028	...	....	....	....	....
81....	A.H.M., Nov. 21 to 22, 1905....	3.880	2.794	....	....	....	....	....
82....	H.C.K., Nov. 24 to 25, 1905....	3.451	6.714	....	....	....	....	....
83....	H.R.D., Dec. 5 to 6, 1905....	.517	.628	....	....	....	....	....
85....	N.M.P., Dec. 9 to 10, 1905....	[2]4.582	1.461	....	....	....	....	....
89....	D.W., Jan. 10 to 11, 1906....	5.857	1.805	....	....	....	....	....
	Ave. of above experiments...	3.847	2.453	0.898	0.416	0.408	0.387	0.420

[1] Not determined.
[2] Does not include possible amount in urine lost.

The data in table 215 show that the chlorine excretion during the fasting is markedly different for different individuals and, indeed, during different experiments with the same individual. The conditions which determine the variations in this chlorine excretion are not clear.

The chlorine excreted in the urine was determined in many of the Middletown fasting experiments. The results are given in table 216.

* Loc. cit.

The data given above are of interest because they give some idea of the relation of the chlorine output to the length of the period of inanition. The variations in the amount of chlorine excreted on the first day of the several fasts are large, ranging from the very small excretion in experiment No. 83, namely, 0.517 gram to 8.898 grams in experiment No. 80. The average of all the experiments for the first day is 3.847 grams. These wide variations on the first day indicate clearly that the excretion must be influenced to a very great degree by the quantity of soluble chlorides taken with the food and drink of the preceding day.

On the second day of the fast the variations are nearly as extreme, ranging from 0.466 gram in experiment No. 73, to 6.714 grams in experiment No. 82. The average for the second day of all the experiments is 2.453 grams. In three of the experiments, Nos. 79, 82, and 83, the excretion of chlorine on the second day was greater than that of the first day. Considering only the experiments with S. A. B.; the second day invariably showed a diminished excretion as compared with the first, although there is no regularity in the per cent of decrease. Thus in experiment No. 73, there is a decrease of about 1.2 grams in the excretion, in experiment No. 75, 0.11 gram, and in experiment No. 77, in which there was an unusually large excretion on the first day, i. e., 5.294 grams, the excretion on the second day fell to 1.671 grams.

Three experiments in which the chlorine was determined continued for three days or more. The excretion on the third day averaged 0.898 gram. A decrease in the first two experiments was observed, but there was an actual increase in the excretion on the third day of experiment No. 77 over that of the second day.

The continued high output of chlorine in experiment No. 77 is difficult to understand except on the supposition that this subject must excrete soluble chlorides rather slowly. From the large excretion on the first day of the experiment, it is apparent that the body contained much more chlorine at the beginning of this fast than at the beginning of either of those preceding. The absolute rise on the third day of the experiment is difficult to explain. The abnormalities in the urinary constituents during experiment No. 77 have frequently been pointed out.

Not until the fourth day of fasting is reached is there anything approximating constancy in the excretion of chlorine for this subject. The variations here are from 0.245 to 0.647 gram, the average excretion being 0.416 gram. On the fifth day of experiment No. 75, the chlorine output was not determined. For experiment No. 73, it amounted to 0.408 gram, a little less than the average for the fourth day. In the one experiment in which the determinations were made for the sixth and seventh fasting days, the chlorine elimination is practically constant.

It thus appears that during fasting the excretion of chlorine may be considerable on the first two days, a smaller amount appearing usually on the second day. There is a marked decrease in the total excretion on the third day. On the fourth day the elimination decreases to about 0.4 gram and remains fairly constant for the three days following.

The results obtained in these experiments are also of interest in discussing the question of the existence of an excessive amount of chlorine in the body over and above what is needed in the system. According to Munk's (7) conception, man has become accustomed to much larger amounts of sodium chloride than have actually been needed, and hence there is in the body an excess which is rapidly eliminated on fasting. A more recent statement of this view has been given by Magnus-Levy.[*] An examination of the data given in table 215 shows that in nearly all the earlier experiments considerable amounts of chlorine were excreted on the first days of the fast. In general, the excretion diminished considerably after the second day. In practically all cases, the excretion remained above 0.7 gram. The marked exceptions to this in previously published work on fasting are the fifth and sixth days of the fast of Breithaupt and the fifth, sixth, and seventh days of the fast of Flora Tosca. On the basis of the results obtained on Cetti and Breithaupt, as well as the earlier results on Succi, Munk contends that there is a considerable accumulation of chlorine in the body which may amount to 10 or 15 grams. This is excreted during the first days of fasting, after which the excretion becomes constant. The data for the chlorine elimination on the later days of the fast with Succi indicate that about one-half a gram of sodium chloride was excreted per day.

The data for the Middletown experiments, on the other hand, show markedly different results. While in the series of 2-day experiments, the chlorine excretion is perfectly comparable to that of the earlier experiments with one or two exceptions, in the long fasts with S. A. B., especially experiments Nos. 73 and 75, the rapid excretion of any chloride accumulated in the body is not observed. Indeed, even during the seven day fast, although to be sure the data for the fifth day are missing, the total elimination of chlorine is (allowing 0.450 as the elimination for the fifth day) less than 5 grams. Extremely low results, also, are observed in experiment No. 73. Singularly enough, in experiment No. 77, the chlorine excretion is more nearly in accord with the results of earlier observations.

A possible explanation of the extremely small output of chlorine in experiments Nos. 73, 75, and 77 may be found in the fact that the subject of the experiments, S. A. B., used food largely of a vegetable nature, and practically no table salt. It was the opinion of the assistants who weighed and prepared

[*] Physiologie des Stoffwechsels. Sonder-Abdruck aus; von Noorden, Handbuch der Pathologie des Stoffwechsels (1906), p. 451.

his food, that in the latter part of the first nitrogen metabolism experiment, i. e., the days immediately preceding experiment No. 77, he consumed considerably more table salt than formerly. Unfortunately, weighings of the salt consumed were not made and hence this impression lacks scientific verification. An inspection of the menus of the food consumed during the nitrogen metabolism experiments would tend to verify this observation, since the subject used a little meat, which was contrary to his earlier custom. The subject of experiment No. 83 reports, on the other hand, that it is his custom to use average amounts of table salt, but the term "average" is at best vague. It is hardly probable that with the large amount of food eaten by the subject, S. A. B., during all the periods between the fasting experiments, there was not a considerable amount of sodium chloride consumed with the food, although a comparatively small amount of cooked food was commonly taken. Unfortunately, data regarding the retention of sodium chloride after the fast are lacking. Taking the data as presented in table 216, the results of experiments Nos. 73, 75 and 83, and indeed those of No. 77, certainly do not point toward the excretion of any considerable amount of excess chlorine accumulated in the body prior to the fast.

A striking exception to the general trend of the experiments is seen in experiment No. 83, in which the chlorine excretion on the two days of the fast was 0.517 and 0.628 gram respectively. The analyses were repeated several times and the possibility of error seems to be eliminated.

Proportion of sodium chloride in ash.—Since in all probability soluble chlorides consumed with the food on the day immediately preceding the fasting period are rapidly excreted and thereby appear in large measure on the first days of the fast, it is of interest to note the proportion of total ash which is represented by the chlorides. While Munk has shown (7) that the chlorine in the urine is to a certain extent combined with bases other than sodium, the amount of chloride other than sodium chloride is relatively small and for purposes of comparison we may assume that all the chlorine that is excreted is combined with sodium. The amounts of sodium chloride calculated as excreted in the urine are recorded in table 217, and in this table the proportion of the total ash represented by sodium chloride is likewise recorded.

The largest excretion of sodium chloride is commonly found on the days when there was the largest excretion of ash. Thus, on the first day of experiment No. 80 when there were 18.93 grams of total ash, it is computed that there were 14.69 grams of sodium chloride. Similarly on the first days of experiments Nos. 85 and 89, the large amounts of total ash are accompanied by large amounts of sodium chloride. The lowest percentages observed in the first two days of fasting are those found in experiment No. 83.

Ash other than sodium chloride.—The very considerable fluctuations in the amounts of sodium chloride excreted in the urine from day to day make a comparison of the ash other than sodium chloride on different days of interest,

and while somewhat extraneous to the general matter under discussion in this particular section, the quantities of ash other than sodium chloride have been computed and placed in table 217. These amounts of ash are seen to be much more uniform than the total ash as determined, and from the regularity of the sulphur and phosphorus eliminations, it is to be expected that the ash other than sodium chloride would remain practically constant throughout the experiment. The second day of experiment No. 77 shows the largest amount of this portion of the total ash, amounting to 9.22 grams. In general, the excretion of ash other than sodium chloride is not far from 5 grams per day.

TABLE 217.—*Proportion of sodium chloride in ash of urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	Ash.	Sodium chloride.	Ash other than sodium chloride.	Proportion of sodium chloride in ash.
73	S. A. B.:	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
	Jan. 28–29, 1905	9.96	2.69	7.27	27.0
	Jan. 29–30, 1905	6.23	0.77	5.46	12.4
	Jan. 30–31, 1905	5.74	0.26	5.48	4.5
	Jan. 31–Feb. 1, 1905	6.09	0.59	5.50	9.7
	Feb. 1– 2, 1905	6.02	0.67	5.35	11.1
75	S. A. B.:				
	Mar. 4– 5, 1905	6.03	2.39	3.64	39.6
	Mar. 5– 6, 1905	7.54	2.21	5.33	29.3
	Mar. 6– 7, 1905	6.44	1.02	5.42	15.8
	Mar. 7– 8, 1905	7.80	0.41	7.39	5.3
	Mar. 8– 9, 1005	7.48	[1]....	....	....
	Mar. 9–10, 1905	5.85	0.64	5.21	10.9
	Mar. 10–11, 1905	5.27	0.69	4.58	13.1
77	S. A. B.:				
	Apr. 8– 9, 1905	13.88	8.74	5.14	63.0
	Apr. 9–10, 1905	11.98	2.76	9.22	23.0
	Apr. 10–11, 1905	10.55	3.17	7.38	30.0
	Apr. 11–12, 1905	9.14	1.07	8.07	11.7
79	H. E. S.:				
	Oct. 13–14, 1905	8.73	4.82	3.91	55.2
	Oct. 14–15, 1905	11.17	5.98	5.19	53.5
80	C. R. Y.:				
	Oct. 27–28, 1905	18.93	14.69	4.24	77.6
	Oct. 28–29, 1905	12.52	6.65	5.87	53.1
81	A. H. M.:				
	Nov. 21–22, 1905	12.61	6.40	6.21	50.8
	Nov. 22–23, 1905	11.22	4.61	6.61	41.1
82	H. C. K.:				
	Nov. 24–25, 1905	9.67	5.69	3.98	58.8
	Nov. 25–26, 1905	16.33	11.08	5.25	67.9
83	H. R. D.:				
	Dec. 5– 6, 1905	8.19	0.85	7.34	10.4
	Dec. 6– 7, 1905	8.73	1.04	7.69	11.9
85	N. M. P.:	[2]0.36	[2]0.22	0.14	61.1
	Dec. 9–10, 1905	12.47	7.56	4.91	60.6
	Dec. 10–11, 1905	5.57	2.41	3.16	43.3
89	D. W.:				
	Jan. 9–10, 1906	13.34	9.67	3.67	72.5
	Jan. 10–11, 1906	7.45	2.98	4.47	40.0

[1] Not determined. [2] Calculated. See p. 248.

WATER OUTPUT.

No other compound exists in the body in such large proportions as does water. The fluctuations in the amount of water in the body during inanition, therefore, demand special study. During fasting experiments as ordinarily conducted, drinking-water is allowed, and hence the relations between the amounts of drinking-water and the amounts of water excreted either through the kidneys or lungs and skin are likewise of importance.

In discussing the volume of urine during fasting, considerable emphasis was laid upon the relation between the amount of water consumed and the volume of urine, and specifically the water in urine.[a] It was there pointed out that while, in general, the ingestion of large volumes of water was accompanied by large volumes of water in the urine, at the same time there were marked exceptions to this general rule. These exceptions imply that the water of urine is an excretory product governed by definite laws, the nature of which is as yet but little understood. Since, in nearly all experiments heretofore made with fasting men, an accurate measure of the total water excretion is lacking, the data obtained in these experiments will, it is hoped, be of value in explaining the nature of the apportionment to the kidneys, lungs, and skin of the water excreted by the body.

Since drinking-water was allowed *ad libitum* in all the experiments here reported, the actual loss of water to the body was less than the loss occurring during complete abstinence from water as well as food.

The amounts of drinking-water consumed by the various subjects were widely different in different experiments. In certain experiments, the subjects were especially requested to consume large quantities of water, but in the series of 2-day fasting experiments, the subjects as a rule consumed only as much as was actually desired, the amount taken rarely exceeding 1000 grams. On one day but 115.1 grams were consumed. The data for the amounts of water consumed are given in table 193.

While under ordinary conditions when food is eaten, some water may be furnished the tissues by the oxidation of the organic hydrogen of the food, in fasting experiments where no food is ingested the water of oxidation of organic hydrogen must be formed from the organic hydrogen of the body material broken down. The proportions of water thus formed may be more properly studied after the consideration of the katabolism of body material. Thus, it is important to recognize that while the water output consists for the most part of preformed water, varying amounts resulting from the oxidation of organic hydrogen are present in the water excreted.

Excretion of water from the body may take place in three ways; through the lungs and skin, i. e., water of respiration and perspiration; through the urine; and through the feces.

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[a] For discussion of the relation of the water in urine to water consumed, see page 348 and table 193 (p. 355).

WATER OF FECES.

From the discussion of feces (see page 337), it can readily be seen that the isolation of so-called "fasting feces," namely, feces, the organic matter of which may be said to be derived from the disintegration of body material, is extremely difficult. The excretion of water in feces, however, can be readily determined. Unfortunately, careful determinations of water in feces were not made in some of the Middletown experiments, since it was apparent that the feces had resulted from the ingestion of food prior to the fast. Errors are thereby undoubtedly introduced, since the water of the feces was actually excreted. In the food experiments, it has been assumed that certain amounts of water were excreted in this way, and the preformed water lost has been calculated on this assumption.

While normal feces contain not far from 70 to 80 per cent of water, during fasting, the feces are usually retained for a considerable period of time, become hard and pilular, and consequently have a much smaller water content. The exigencies of experimenting in one instance called for the removal of fecal matter by means of an enema, and hence in this connection it was difficult to determine the water actually excreted with the feces.

WATER OF URINE.

Large amounts of water are excreted in the urine during fasting. In a preceding section the ratio of water of urine to water of drink has been discussed at length (see p. 348).

WATER OF RESPIRATION AND PERSPIRATION.

Considerable quantities of water are evaporated from the lungs and skin and it becomes necessary in accurate metabolism experiments to measure the amounts lost. Since each gram of water vaporized requires the absorption of 0.592 calorie of heat, the influence of the water of respiration and perspiration on the heat output is very marked, and consequently for the accurate determination of the heat production careful measurement of the water of respiration and perspiration is necessary. Furthermore, an accurate record of the water of respiration and perspiration is essential for determining the amount of preformed water excreted, and the water resulting from the oxidation of organic material in the body.

The difficulties attending the collection and analysis of the respiratory gases have precluded, in practically all of the earlier experiments on fasting, a study of the amounts of water vaporized from the lungs and skin. Although the amount of carbon dioxide has been frequently determined, unusual difficulties attend the accurate measurement of loss of water from the body. The fluctuations in the relative humidity inside the respiration chamber, hygroscopic

nature of clothing, furniture, etc., and difficulties attending the accurate record of body-weight, all tend to vitiate the accuracy of the indirect determination of water-vapor as heretofore made.

To be sure, a fairly close approximation can be obtained by means of the so-called "insensible loss," which can be computed from the changes in body-weight from the beginning to the end of the day, the weights of urine and feces, and the weights of drinking-water, provided there is a determination of the amount of carbon dioxide exhaled. In the experiments on Cetti and Breithaupt reported by Munk (7), the respiratory quotient and consequently the carbon dioxide elimination was determined on different days but only for short periods each day. From these determinations, the authors calculated the total carbon dioxide elimination for the 24 hours. Thus, the data were obtained for computing the insensible loss in these experiments.

In the 10 days of Cetti's experiment, it was computed that there were 8016 grams of water of respiration and perspiration, an average of 802 grams per day.[97] From the determinations of the amount of protein katabolized, and likewise from the estimations of fat oxidized, on the basis of the respiratory experiments made with the Zuntz apparatus, the authors apportioned the amount of water vaporized in terms of water of oxidation of organic material and water lost from the body itself. Similar results were reported for Breithaupt in a 6 days' fast in which there were 4199 grams (700 grams per day) of water of respiration and perspiration.

The errors involved in computing the daily absorption of oxygen and elimination of carbon dioxide from respiration experiments lasting but 10 to 20 minutes are obvious, and the errors which affect the measurement of the carbon dioxide elimination likewise affect the estimations of the water of respiration and perspiration. Nevertheless, the results obtained by this method are by no means as inaccurate as one might suppose.

By means of the more accurate determination of the total elimination of carbon dioxide with the Tigerstedt apparatus, the water of respiration and perspiration was computed in the experiments on J. A. (9). The objections to the determination of carbon dioxide in short periods did not here obtain, and although the subject left the respiration chamber each day for a period of two hours, the estimation for the remainder of the day was unquestionably extremely accurate. When computed for the 24 hours of the day, the result represents the probable carbon dioxide output of a fasting man under the conditions of muscular activity obtaining while in the respiration chamber. An important factor in the indirect determination of the amount of water of respiration and perspiration is, however, the change in body-weight. Since the subject J. A. was outside the respiration chamber at least 2 hours of the

[97] (7), p. 114.

day and during that time his muscular activity was much greater than in the period inside the chamber, the losses in body-weight are in all probability too large for the accurate computation of the water vaporized. From the loss in body-weight and the carbon dioxide output, the water of respiration and perspiration was computed. The amounts thus found were for the 5 days 1058, 931, 662, 1329, and 803 grams.

A much more desirable method of obtaining the water of respiration and perspiration is that in which the subjects are inclosed in a respiration chamber and the water-vapor in the ventilating air-current accurately measured. The difficulties attending this determination are much greater than at first sight would appear. The bedding and other articles inside the chamber are prone to absorb or give off water and, indeed, in considerable amounts. To make a complete determination of the amount of water-vapor eliminated from the lungs and skin of the subject, therefore, necessitates, in addition to the measurement of the water-vapor in the air, a record of the changes in weight of bedding and other articles in the chamber.

It is of special interest to note that the respiration chamber of Pettenkofer[98] was used first to study the metabolism of fasting man. The experiments were made by Ranke.[99] From the carbon dioxide output and the changes in body-weight, Ranke computed the water of respiration and perspiration in three 24-hour fasting experiments to be 609, 1080, and 537 grams. The room temperatures were 19.5°, 25.4°, and 16.4°, respectively. On the last day no water was consumed.

Direct determinations of the water-vapor output of fasting man were first reported by Pettenkofer & Voit.[100] These writers early recognized the difficulties attending water determination, and the observations regarding changes in the weights of bedding, etc., are fully in accord with those of present day experiments.

The experiments of these investigators lasted 24 hours. During this period the water determinations showed an elimination of 828.9 grams of water of respiration and perspiration in one experiment and 814.1 grams in another. 800
In the third fasting experiment, during which, however, the subject engaged in considerable muscular work, the water of respiration and perspiration amounted to 1778.5 grams. While unquestionably the results obtained by Pettenkofer & Voit are the resultant of a number of errors which are more or less compensating, the fact remains that these observers recognized the desirability of determining the water-vapor directly instead of computing the insensible loss, and they also planned their experiments to cover 24 hours.

The next successful attempt to determine directly the water-vapor eliminated by fasting man was that of Sadovyen (2). Two experiments were made, one

[98] Annalen der Chemie u. Pharm. (1862), II, Supplementband, p. 1.
[99] Archiv Anat. u. Physiol. (1862), p. 340.
[100] Zeitschr f. Physiol. (1866), 2, p. 478.

of two days' duration in which no drinking-water was taken, and the other of four days during which water was consumed. The subject remained in the respiration chamber the larger part of each 24 hours. Usually the periods during which the experimental observations were recorded were of 9 to 10 hours' duration, and from the results obtained during these periods, the amounts for 24 hours were computed. On the 2 days of the first experiment the water of respiration and perspiration amounted to 961 and 831 grams, respectively, and for the 4 days of the second experiment, the amounts were 730, 709, 597, and 713 grams. Although the subject spent a portion of the day outside the respiration chamber with somewhat greater muscular activity, these results are not liable to the same criticism raised regarding the observations made on J. A., since the loss of body-weight does not enter into the computation for 24 hours.

The Pashutin respiration apparatus was likewise used in an experiment in which the water of respiration and perspiration was determined by Likhachev.[181] In this experiment the subject remained 26 hours and 10 minutes inside the chamber, and from the observations thus made, the amounts for 24 hours were computed, thus marking a distinct advance in accuracy over the experiments of Sadovyen. In the 1-day fasting experiment, the water-vapor output was 664 grams, or 10.68 grams per kilo of body-weight. No records are given of changes in weight of the furniture and other articles inside the chamber.

In the four earlier fasting experiments made in this laboratory and previously reported,[182] the water of respiration and perspiration was determined. No attempt was made in these experiments to allow for any changes in weight of the bedding and furniture. The amounts of water of respiration and perspiration for the different days were: experiment No. 36 (1 day), 768 grams; experiment No. 39 (1 day), 822 grams; experiment No. 42 (1 day), 842 grams; experiment No. 51 (2 days), 1018 and 895 grams, respectively.

The particular type of respiration apparatus used in these experiments is especially adapted for the measurement of the quantity of water in the ventilating air-current. Furthermore, since in all but one (experiment No. 59) of the experiments here reported, special precautions were taken to secure reliable weighings of the bedding and other articles in the chamber of the apparatus, corrections for variations in the moisture content of these articles could be applied to the other measurements of water-vapor and the water of respiration and perspiration be accurately measured. Without the use of a respiration chamber and accurate balance for noting the gain or loss in weight of the articles in the chamber, accurate measurements of the water of respiration and perspiration are impossible.

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[181] The production of heat by healthy man in a condition of comparative rest. A. A. Likhachev, Inaug. Dissertation (Russian), 1893, St. Petersburg.
[182] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

The results obtained in the fasting experiments here reported are given for each day in table 218, the detailed determinations for the 2- and 3-hour periods being given in the statistical tables for the different experiments.

TABLE 218.—*Water of respiration and perspiration in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59....	B.F.D., Dec. 18–20, 1903....	982	952	943	....	....	....	....
68....	A.L.L., Apr. 27–28, 1904....	745	761	....	....	....	....	....
69....	A.L.L., Dec. 16–19, 1904....	738	898	795	728	....	....	....
71....	S.A.B., Jan. 7–10, 1905....	745	665	568	518	....	....	....
73....	S.A.B., Jan. 28–Feb. 1, 1905.	684	636	602	569	543	....	....
75....	S.A.B., Mar. 4–10, 1905....	650	642	658	596	579	542	543
77....	S.A.B., Apr. 8–11, 1905....	670	618	638	627	....	....	....
79....	H.E.S., Oct. 13–14, 1905....	667	704	....	....	....	....	....
80....	C.R.Y., Oct. 27–28, 1905....	927	1061	....	....	....	....	....
81....	A.H.M., Nov. 21–22, 1905....	609	671	....	....	....	....	....
82....	H.C.K., Nov. 24–25, 1905....	842	940	....	....	....	....	....
83....	H.R.D., Dec. 5– 6, 1905....	685	672	....	....	....	....	....
85....	N.M.P., Dec. 9–10, 1905....	776	813	....	....	....	....	....
89....	D.W., Jan. 10–11, 1906....	820	803	....	....	....	....	....
	Average............	753	774	701	607	561	542	543

The figures in table 218 show that the variations between different days with different subjects are very considerable, ranging from 518 grams on the fourth day of experiment No. 71 to 1061 grams on the second day of experiment No. 80. It is to be noted that these subjects were performing no muscular work other than that incident to the ordinary habits of life inside the chamber.

Considering all the experiments, the variations on the first day of the fast range from 609 to 982 grams, the average being 753 grams. On the second day of the fast, the range is from 618 to 1061 grams, the average for all the experiments being a little more than that on the first day, namely, 774 grams. The smaller number of experiments which lasted three or more days show a range on the third day from 568 to 943 grams, the average being 701 grams. As the fast progresses, the average amount of water of respiration and perspiration per 24 hours gradually diminishes, but for the last 3 days of fast, as here recorded, the amount is nearly constant.

Considering the experiments with the same subject, the agreement between Nos. 68 and 69 is fairly close, the second day of experiment No. 69 being an exception. On this day there were 160 grams more water given off than on the day preceding.

The extended series of experiments with S. A. B. show that for the most part on the first day without food, the amount of water was fairly constant, ranging

from 650 to 745 grams. On the second day there is much less variation, the minimum and maximum being 618 and 665 grams. The difference between the lowest and the highest amounts on the third day is 90 grams, and on the fourth day about 100 grams.

In general, as the fast progresses, there is a diminution in the amount of water vaporized. This is especially noticeable in the longer fasts with S. A. B.

The absolute amounts of water excreted in the respiration and perspiration are on the whole considerably smaller than those usually found with resting subjects. For example, in the numerous rest experiments with food made in this laboratory and previously reported, the lowest amount of water of respiration and perspiration recorded is 697 grams[103] with E. O. and the highest amount is 1212 grams with the same subject. The average of all the rest experiments gives a water excretion from lungs and skin of 935 grams.[104]

The possible factors affecting the elimination of water-vapor are the absolute amount of water in the body, including the drinking-water, the relative humidity of the air in the respiration chamber, and the muscular activity of the subject.

Ratios between the water of respiration and perspiration and amounts of drinking-water.—The ratios between the water in the urine and the water consumed have received special discussion on page 348. It was there seen that while, in general, large amounts of drinking-water were accompanied by large volumes of urine, there is no definite ratio between the volume of urine and the volume of water consumed. Especially is this the case in experiments in which very small volumes of water were taken. The effect of the ingestion of large quantities of water on the elimination of water-vapor can be studied by means of the data obtained in these experiments, since the amount of water consumed each day, as well as the water of respiration and perspiration, was accurately measured. The ratios between the water of respiration and perspiration (table 218) and the amounts of drinking-water, as recorded in column *a* of table 193, have, therefore, been computed.

The results show widely varying ratios, the lowest being that for the third day of experiment No. 73, namely, 0.218, i. e., for every 1000 grams of water consumed there were but 218 grams of water of respiration and perspiration. The largest ratio is that of the first day of experiment No. 89, namely, 7.121. On this day the subject consumed an unusually small amount of water, i. e., 115.1 grams, while the water of respiration and perspiration was 820 grams.

The ratios in the experiments with S. A. B. are more nearly constant. In experiment No. 71, the ratios for the 4 days are 0.618, 0.337, 0.245, and 0.348,

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[103] A special experiment, in which abnormal ventilation conditions obtained, is reported in U. S. Dept. Agr., Office of Expt. Sta. Bul. 175. In this experiment the water vaporized from the body was 267 grams.

[104] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136, p. 137.

averaging 0.358. In experiment No. 73, the ratios are 0.329, 0.232, 0.218, 0.291, and 0.505, averaging 0.286. In experiment No. 75, the ratios are remarkably constant, i. e., 0.330, 0.371, 0.311, 0.312, 0.366, 0.318, and 0.321, averaging 0.331. The ratios for experiment No. 77 are somewhat larger, i. e., 0.327, 0.400, 0.606, and 0.651, averaging 0.454. With the series of experiments with S. A. B., therefore, it would appear that there is a possible ratio between the water of respiration and perspiration and the amount of drinking-water. Nevertheless, it must be borne in mind that only on one day in all the experiments with S. A. B. did the drinking-water consumed fall below 1000 grams. That there can be no definite ratio can readily be seen from the fact that on the first day of experiment No. 73 when the subject drank 2082 grams of water, the water of respiration and perspiration was 684 grams, while on the second day, with a very considerable increase in drinking-water (total 2747 grams), the water from the lungs and skin was actually lower, i. e., 636 grams. Furthermore, in experiment No. 71 on the third day, the amount of water consumed was nearly twice that on the first day, while the amount of water in respiration and perspiration was nearly 200 grams less. In the shorter experiments, Nos. 79, 81, and 85, there was also in each instance a decrease in the amount of water consumed on the second day over the first, accompanied by an actual increase in the water of respiration and perspiration. Considering all the experiments seven show an increase in the water of vaporization on the second day.

In general, the water of respiration and perspiration remains fairly constant on the different days of the same experiment, there being a slight though persistent diminution as the experiment proceeds. Frequently there is a parallel diminution in the amount of drinking-water, but in certain instances, especially in the two cited above, the contrary is true. Since, therefore, there is such relative constancy in the water of respiration and perspiration and such wide variations in the amount of water consumed, it is obvious that the ratio between the water vaporized from the body and the water consumed must show marked fluctuations.

It is difficult, therefore, to trace any relationship between the amount of drinking-water consumed and the elimination of water-vapor. As a matter of fact, since all of the experiments here compared were made under conditions of rest, what is recorded as water of respiration and perspiration is practically confined to the water-vapor leaving the lungs and skin.

The absence of any apparent influence of the amount of drinking-water on the water of respiration and perspiration in these fasting experiments is in accord with the observations of Laschtschenko,[168] who made a number of experiments in a Pettenkofer respiration apparatus to study the influence of the in-

[168] Archiv f. Hygiene (1898), 33, p. 145.

gestion of large amounts of water on the water-vapor output of man. The experiments did not include observations during a period of inanition.

The figures in tables 193 and 218 permit a comparison of the water of respiration and perspiration with the water in the urine, although no ratios between these two factors have been computed and tabulated. As is the case with the water of respiration and perspiration, the water in the urine tends to diminish as the fast progresses, and yet in experiments Nos. 69, 71, and 75 the contrary is true. Furthermore, on the second day of experiment No. 73, on which the largest amount of water in the urine (2928 grams) was voided, the total water-vapor output was but 636 grams, while with the same subject on the first day of experiment No. 71, where the water in the urine was about one-third of that on the second day of experiment No. 73, the water of respiration and perspiration was more than 100 grams larger. No relation, therefore, appears between the amount of water in the urine and the amount of water-vapor eliminated.

Influence of the water content of the body.—As will be seen from the discussion on page 467, there is material loss of preformed water from the body as the fast progresses, hence it might be contended that the restricted elimination of water-vapor may partly be accounted for by the lowering of the absolute amount of water present in the body. On the other hand, the actual amount of preformed water lost from the body is but a small proportion of the total water in the body and the percentage of water present in the body is hardly affected by the losses in fasts as short as are these under discussion. It does not seem reasonable, therefore, to conclude that the relatively small losses of preformed water from day to day can influence appreciably the diminution in the output of water-vapor noted as the fast progresses.

Influence of variations in relative humidity.—As the air comes in contact with the moistened mucous membrane of the mouth, nose, throat, and lungs, water is rapidly evaporated from these tracts and the exhaled air has commonly been assumed to be saturated with water-vapor at the temperature of the body.

Air is inspired at the relative humidity of the air in the chamber. The lower the humidity, the greater the amount of water-vapor taken up by the air, as it passes through the lungs. Similarly, as the air comes in contact with the surface of the body, the lower the humidity the greater the amount of water-vapor taken up. We should then, naturally, expect to find that the amounts of water given off by the body per day would in the majority of instances be affected by the relative humidity of the air, although the influence of the relative humidity of the air might or might not be so great as to obliterate any other factors.

An examination of the total amount of water remaining in the chamber at the end of each period, as given in the detailed tables in connection with these

experiments, shows that as a rule the relative humidity of the air inside the chamber becomes lower and lower as the fast progresses. The percentage relative humidity is determined in large measure by the rate of ventilation of the chamber. The more rapid the rate of ventilation, the greater the amount of air withdrawn and completely deprived of its moisture by passing through concentrated sulphuric acid, and hence the larger the volume of dry air returned to the chamber. While in the 2-hour periods it is more than probable that the rate of speed of the electric motor and consequently the volume of air passing through the chamber may vary considerably, it is highly improbable that in the course of 24 hours any marked variations in the amounts of air passing through the chamber are to be observed. In the earlier series of experiments made with the apparatus in a very different form, a mechanical air pump was used and a large number of records were obtained to show the total ventilation per 24 hours. Inasmuch as the same electric motor, shafting, fittings, etc., aside from substituting a rotary blower for the mechanical air pump, are now used, the conditions are not different now than they were before. At that time all the air passing through the chamber was first caused to pass through a large gas meter and thus a record of the total ventilation was obtained. The total ventilation for a large number of days rarely altered more than 3 or 4 per cent from day to day.[169]

It seems probable that the rate of ventilation stays reasonably constant. Under these circumstances, then, any fall in the relative humidity must be ascribed to a diminished loss of water from the body through the lungs and skin and the figures given in table 218 show that this is actually the case. Since, then, there is a diminishing loss of water of respiration and perspiration from the body, even with a markedly diminished relative humidity, it seems clear that at least in experiments with fasting men some factor other than relative humidity determines the loss of water of respiration and perspiration.

Influence of muscular activity.—The only remaining factor that seems in any way connected with the formation of water of respiration and perspiration is muscular activity. The frequent observations that excessive muscular activity results in profuse sensible perspiration justify the assumption that even minor muscular activity would cause an increase in the insensible perspiration over that commonly occurring during rest. It might be expected, furthermore, that the muscular activity would determine to a considerable extent the degree of insensible as well as sensible perspiration.

The muscular activity in experiments of this nature may be measured relatively by three methods: (1) The record of the muscular movements of the subject obtained from the diary, notes of assistants, etc.; (2) the carbon dioxide production, which is an approximate index of muscular activity; and

[169] See table 120, pp. 273-300, U. S. Dept. Agr., Office of Expt. Sta. Bul. 136, in which the ventilation per 24 hours is given for experiments from 35 to 55 inclusive.

(3) the heat production, which varies directly with the muscular activity. By comparing the estimated amount of muscular activity (derived by the above methods) with the quantities of water-vapor in respiration and perspiration, any relationships existing between them may readily be observed.

As the result of observations in a large number of experiments on muscular work,[197] it has been found that excessive muscular work produces an enormous increase in the water vaporized from the lungs and skin. It has been definitely shown that when sensible perspiration appears, there is a noticeable increase in the water-vapor output accompanying muscular work. On the other hand, when no extraneous muscular exercise is taken, it is difficult to demonstrate the influence of minor muscular activity on the water-vapor output. In all the experiments here reported, the subjects were practically at rest, with the single exception of the second period of experiment No. 71 when the subject rode a bicycle ergometer for 10 minutes. There was no visible perspiration, however, in this short period of exercise. The marked differences in the elimination of water-vapor, therefore, must be explained by some factors other than marked muscular activity, for the daily routine of the subjects was not unlike, as is seen by comparing the records of body movements. However, that there were marked differences in the sum total of bodily activities, not only in experiments with different subjects but also on different days of the same experiment, is shown in the discussion regarding muscular activity. A comparison of the relative amounts of muscular activity there estimated with the amounts of water-vapor leaving the lungs and skin shows that there is a distinct relation between even the minor differences in muscular activity as estimated and the actual water-vapor output.

The problem is, however, not as simple as it first appears, for on the assumption that even minor differences in muscular activity produce wide variations in the total quantity of water vaporized, we should expect to find a much smaller vaporization of water during the night period of all the experiments, when the subjects were asleep, than during the day period. This is not invariably the case as is shown in the discussion in the next section.

The periodic elimination of water-vapor.—Opportunity was offered in the experiments here reported to study the periodicity of the output of water-vapor during the experimental day. The experimental periods were all of 2 hours' duration. Since unusual care was taken in the measurement of the water-vapor and comparatively small changes in the weight of the bed, bedding, etc., occurred in a majority of the experiments, the results give an accurate measure of the water-vapor output for the different periods of the day. The methods of applying the corrections for the changes in weight of the bed and bedding have been explained previously. The results for both the fasting and the food experiments are given in detail in table 219. In this table is recorded the

[197] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

TABLE 219.—*Elimination of water of respiration and perspiration during different periods of the day in metabolism experiments with and without food.*

	7 a.m. to 9 a.m.	9 to 11 a.m.	11 a.m. to 1 p.m.	1 to 3 p.m.	3 to 5 p.m.	5 to 7 p.m.	7 to 9 p.m.	9 to 11 p.m.	11 p.m. to 1 a.m.	1 to 3 a.m.	3 to 5 a.m.	5 to 7 a.m.
Fasting experiments.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
No. 69, Dec. 16-17, 1904.....	75.2	59.8	61.0	61.0	58.6	54.9	58.4	55.6	60.6	60.3	67.2	65.8
Dec. 17-18, 1904.....	84.9	68.9	64.2	66.9	69.3	71.0	67.7	65.2	85.0	89.2	88.7	77.4
Dec. 18-19, 1904.....	80.2	67.4	69.4	63.9	65.3	67.1	65.1	59.7	60.3	70.0	73.8	52.6
Dec. 19-20, 1904.....	70.8	55.6	61.8	59.2	62.0	61.9	61.2	59.1	60.5	58.0	61.5	56.4
No. 71, Jan. 7- 8, 1905.....	81.6	81.2	69.9	64.3	70.1	66.7	70.5	51.1	55.3	50.7	33.4	50.0
Jan. 8- 9, 1905.....	82.5	67.9	54.5	58.2	50.5	55.7	52.7	49.2	49.1	48.9	44.6	51.4
Jan. 9-10, 1905.....	52.0	51.0	45.0	48.7	48.3	52.1	46.9	48.1	44.2	44.7	43.5	43.1
Jan. 10-11, 1905.....	51.6	42.6	42.5	43.8	43.3	48.4	42.9	39.7	41.6	43.3	40.6	37.5
No. 73, Jan. 28-29, 1905.....	72.9	67.6	59.0	56.4	54.6	58.5	52.9	51.4	54.2	53.6	51.3	51.7
Jan. 29-30, 1905.....	59.0	67.3	54.9	52.3	52.6	55.2	53.5	51.4	48.1	50.2	47.6	44.0
Jan. 30-31, 1905.....	59.0	54.8	52.4	52.2	52.4	51.6	52.7	46.6	46.6	42.7	47.6	44.0
Jan. 31-Feb. 1, 1905.	52.5	49.7	52.2	48.1	45.8	46.6	50.3	46.2	46.6	44.2	43.9	43.1
Feb. 1- 2, 1905.....	51.0	47.2	44.1	45.4	40.2	46.3	48.2	49.9	41.7	43.2	41.4	44.7
No. 75, Mar. 4- 5, 1905.....	72.6	62.4	55.9	51.2	47.4	47.5	48.9	54.0	51.3	50.6	53.7	54.6
Mar. 5- 6, 1905.....	74.2	58.8	51.7	50.6	50.0	49.9	50.4	52.6	49.7	53.6	48.2	52.4
Mar. 6- 7, 1905.....	68.0	58.2	45.4	58.1	53.4	53.8	54.2	54.3	51.2	54.4	54.1	52.8
Mar. 7- 8, 1905.....	52.8	47.6	51.1	52.1	48.3	51.2	48.8	52.9	50.3	46.4	48.9	45.8
Mar. 8- 9, 1905.....	56.4	45.9	50.4	49.4	47.2	45.7	48.3	49.3	45.4	47.4	49.4	44.6
Mar. 9-10, 1905.....	54.1	48.5	46.8	44.8	39.0	43.0	44.5	44.7	43.4	45.2	43.6	44.4
Mar. 10-11, 1905.....	55.1	44.3	46.5	47.3	44.2	43.1	38.0	45.1	45.4	42.4	47.1	44.4
No. 77, Apr. 8- 9, 1905.....	74.0	60.4	56.6	57.7	54.7	54.2	53.7	45.4	52.5	47.7	57.5	55.3
Apr. 9-10, 1905.....	77.8	48.5	49.7	50.1	47.2	48.3	54.8	58.3	53.1	50.9	51.3	47.9
Apr. 10-11, 1905.....	68.4	47.5	50.3	54.7	49.1	50.1	51.3	52.2	43.6	52.6	45.0	52.9
Apr. 11-12, 1905.....	50.2	51.4	49.1	50.8	47.1	59.4	50.8	57.2	53.0	54.7	50.9	52.0
No. 79, Oct. 13-14, 1905.....	53.0	55.4	55.6	55.6	54.8	55.7	52.9	54.4	54.1	63.0	54.2	58.2
Oct. 14-15, 1905.....	55.2	57.7	63.9	57.9	58.8	59.8	61.2	61.5	59.8	61.0	54.2	53.2
No. 80, Oct. 27-28, 1905.....	67.2	47.5	84.2	74.3	75.7	76.1	70.1	71.0	73.2	95.2	88.6	103.7
Oct. 28-29, 1905.....	92.2	77.4	88.0	95.3	89.5	91.9	83.0	83.2	95.2	92.8	85.0	86.9
No. 81, Nov. 21-22, 1905.....	56.1	63.4	54.6	51.8	51.6	52.6	48.3	43.6	46.6	45.6	45.3	49.1
Nov. 22-23, 1905.....	56.5	64.3	55.1	50.9	49.7	58.2	56.4	57.6	55.2	55.8	54.7	56.5
No. 82, Nov. 24-25, 1905.....	99.4	87.0	59.8	72.8	73.8	67.7	70.5	65.3	64.9	50.4	63.6	67.0
Nov. 25-26, 1905.....	110.2	85.8	78.3	75.8	74.4	74.0	84.2	80.2	72.9	57.8	69.5	77.4
No. 83, Dec. 5- 6, 1905.....	68.3	57.4	57.9	53.2	51.7	60.5	58.6	52.8	53.3	61.2	53.4	56.3
Dec. 6- 7, 1905.....	78.8	52.5	59.9	52.3	54.6	54.0	58.1	53.6	55.4	51.8	48.1	52.9
No. 85, Dec. 9-10, 1905.....	76.8	68.4	66.5	59.6	59.6	65.4	73.6	61.3	62.8	60.0	59.9	61.9
Dec. 10-11, 1905.....	73.7	63.4	65.6	61.2	59.9	68.7	70.1	68.9	68.0	72.9	67.9	73.2
No. 89, Jan. 10-11, 1906.....	68.0	64.3	66.1	71.0	64.6	71.1	72.5	73.2	69.2	63.5	68.0	68.2
Jan. 11-12, 1906.....	65.7	61.2	68.5	64.5	61.9	73.7	79.9	69.2	69.9	61.7	64.2	62.4
Average of above:												
First day of fast......	72.1	64.6	62.3	60.7	59.8	60.9	60.9	56.6	58.2	58.5	58.0	61.8
Second day..........	75.9	64.5	62.9	61.3	59.9	63.4	64.3	62.6	63.4	62.2	60.3	61.3
Third day	65.5	55.8	52.5	55.5	53.7	54.9	54.0	52.2	49.2	52.9	52.8	49.1
Fourth day..........	55.6	49.4	51.3	50.8	49.3	53.5	50.8	51.0	50.4	49.3	49.2	47.0
Fifth day............	53.7	46.5	47.3	47.4	43.7	46.0	48.3	49.6	43.6	45.3	45.4	44.7
Sixth day............	54.1	48.5	46.8	44.8	39.0	43.0	44.5	44.7	43.4	45.2	43.6	44.4
Seventh day..........	55.1	44.3	46.5	47.3	44.2	43.1	38.0	45.1	45.4	42.4	47.1	44.4
All days	68.4	59.5	58.1	57.5	55.8	58.2	58.1	56.2	56.1	56.3	55.6	56.2
Food experiments.												
No. 70, Dec. 20-21, 1904.....	75.0	66.8	67.0	65.1	64.6	71.0	65.9	66.7	72.5	90.9	70.6	64.2
Dec. 21-22, 1904.....	75.7	72.8	71.3	73.1	81.9	90.2	101.1	88.3	95.2	95.8	83.9	73.6
Dec. 22-23, 1904.....	86.8	79.6	76.9	70.5	69.9	97.9	105.0	86.9	103.9	110.5	90.1	81.1
No. 72, Jan. 11-12, 1905.....	53.0	51.9	44.0	52.8	46.3	42.0	46.2	40.2	42.3	43.6	39.5	43.3
No. 74, Feb. 2- 3, 1905.....	49.9	52.2	50.6	59.0	51.2	52.6	49.6	51.2	39.7	45.8	39.8	43.2
Feb. 3- 4, 1905.....	40.5	48.4	42.3	49.8	45.4	49.9	41.7	42.8	41.7	41.7	40.3	43.2
Feb. 4- 5, 1905.....	48.7	45.3	42.2	44.9	44.7	49.4	44.1	43.2	40.8	41.6	40.6	39.5
No. 76, Mar. 11-12, 1905.....	57.2	50.1	55.4	55.9	52.0	48.6	54.7	53.1	48.6	47.5	46.8	46.9
Mar. 12-13, 1905.....	51.0	46.5	49.6	50.0	50.4	50.5	50.8	52.5	46.1	46.5	43.4	45.0
Mar. 13-14, 1905.....	58.7	46.0	53.5	52.6	54.6	51.7	56.7	50.1	48.1	46.8	47.6	45.0
Av. of above food exp'ts:												
First day	58.8	55.3	54.3	58.2	53.5	53.5	54.1	52.8	50.8	57.0	49.2	49.4
Second day..........	55.7	55.9	54.4	57.6	59.2	63.5	64.5	61.2	61.0	61.3	55.9	54.0
Third day............	64.7	57.0	57.5	56.0	56.4	66.3	68.6	60.1	64.3	66.3	59.4	55.2
All days	59.6	56.0	55.3	57.4	56.1	60.4	61.6	57.5	57.9	61.1	54.3	52.5

elimination of water-vapor for each period on 38 days of fasting experiments. The larger number of observations were, naturally, on the first and second days. The average excretion of water-vapor for each period on the different days of the fasts is given at the foot of each column and the average excretion for the period in all the fasts is given as a grand average beneath the column for each period. The results for food experiments are also shown in order that any possible effect on this output of water-vapor due to the ingestion of food may be considered.

The first period of the day from 7 a. m. to 9 a. m. is characterized by the largest water-vapor output, and during this period the fluctuations as the fast progresses are especially noticeable. On the second day of fasting the highest average water-vapor output is noted, namely, 75.9 grams, while on the fourth, fifth, sixth, and seventh days, the average amounts are practically constant.

During the period from 9 a. m. to 11 a. m. there is a decrease of 18 grams between the average water-vapor output on the first and second days of fast and the average amounts on the sixth and seventh days. The decrease as the fast progresses is quite regular after the second day, although the difference between the second and third days is rather greater than that between the third and fourth. Considering the period from 11 a. m. to 1 p. m., it will be seen that the elimination is slightly higher on the second day than on the first, but that on the third day it is reduced by about 10 grams. There is then a gradual falling off after the second day.

Similar differences between the first and second days of the fast are observed with practically all the remaining periods of the day, the most noticeable exceptions being the periods from 9 to 11 p. m. and 11 p. m. to 1 a. m., in which there is an increase on the second day of about 5 grams. In general, with all the periods there is a diminution of about 10 grams between the second and third days of fasting.

The largest individual water-vapor output noted in any experiment is that of the second day of experiment No. 82 from 7 a. m. to 9 a. m., 110.2 grams, and the lowest is on the first day of experiment No. 71 from 3 a. m. to 5 a. m., 33.4 grams. This corresponds to about 17 grams per hour.

The average general distribution of the water elimination throughout the day as shown by the grand averages in table 219 indicates that the greatest output of water-vapor, 68.4 grams, occurs during the period from 7 to 9 in the morning. The lowest output occurs between 3 a. m. and 5 a. m., namely, 55.6 grams.

The excessive output during the first period of the day may be explained in two ways: first, the extra muscular effort attendant upon the work of rising in the morning, arranging the furniture, weighing of subject and bedding, and the general activity at the beginning of the experimental day; second, the moisture condensed in the bed clothing over night may be given off during

this particular period in greater amounts than in any other period. This latter factor may likewise partially explain the tendency for the water output to be less during the night, since there may be an accumulation of water in the bedding.

Excluding the period from 7 a. m. to 9 a. m., the average amounts of water-vapor eliminated from the lungs and skin per 2-hour period remain singularly constant, varying from 59.5 in the period 9 a. m. to 11 a. m. to 55.6 from 3 a. m. to 5 a. m., a difference of less than 7 per cent. On the whole, the greatest water elimination takes place during the waking hours and the smallest during sleep.

In the recent study of the periodic elimination of water-vapor by Wolpert & Peters,[108] a much greater variation in the water vaporized is shown per hour than in the averages of these experiments. This, however, is to be expected since their observations were confined to but three experiments. In their experiments the attempt was made to obtain the correction for the changes in weight of the clothing and bedding at the end of each experimental period, which was of 4 hours' duration. To accomplish this, the subject of the experiment removed the clothes and weighed the bed, bedding, and clothing at the end of each period. While, theoretically, this procedure is well designed to give accurate data regarding the water-vapor output, practically, the extraneous muscular activity of dressing and undressing and weighing the clothing is an abnormal one in experiments in which the water-vapor output during rest is to be studied. Furthermore, during the period when the clothing is removed, water is rapidly vaporized from the body as well as from the clothing, and hence there is a vaporization of water much greater than would normally occur with the subject clothed and resting quietly. It is thus seen that the two series of experiments can hardly be compared, although it may readily be contended that the results of the experiments here reported represent more nearly what would be expected to be the water-vapor output of the resting man. This is especially true of the first day of fasting. The factors entering into the later days of fasting obviously would affect the elimination of water-vapor to such a degree that the averages of all these experiments would be distinctly lower than what could be considered a normal for the resting man. Considering only the first day of fasting, the water-vapor output is still noticeably greater during the first period of the day and, aside from this period, it is somewhat larger per hour during the day time than that during the night.

Recognizing the well-known effect of activity on the water-vapor output, it is reasonable to suppose that in these fasting experiments, the large output during the first period may in part at least be accounted for by the extraneous muscular effort. Experiments for the study of the true water-vapor output of resting man should be so designed as to insure regularity of muscular

[108] Archiv f. Hygiene (1906), **25**, p. 299.

activity and conditions which would otherwise obtain during the ordinary rest experiment. The differences between the output during the day time and that of the night are, it is true, not sufficiently great to warrant an assertion that there is a positive increase in the water vaporized from the actual body surface of the man during the day, but making due allowance for the vaporization from the bed clothing, which was in these experiments weighed but once each 24 hours, the evidence still points towards a slightly greater elimination of water-vapor during the day period. The increased respiration rate of the day, thereby causing a greater ventilation of the lungs and a greater vaporization of water, would certainly imply an increased water-vapor output during this period.

Influence of the ingestion of food.—In the few food experiments which are here reported, the data are also given for the comparison of the output of water-vapor during the different periods of the day. While the number of individual experimental days from which the data are drawn is less than half of those of the fasting experiments, the number is sufficient to average and give general information regarding the distribution of the water-vapor output for the day. The differences are much less than in the fasting experiments. A close examination of the table shows that the water of respiration and perspiration on the second and third days of experiment No. 70 was abnormally high in practically all periods. On these two days the subject was evidently in a slightly febrile condition as an examination of the body temperature recorded on page 314 will show. While the data are too meager to draw definite conclusions, they may indicate that slight increases in body temperature affect in a marked degree the elimination of water-vapor, and from the results upon these two days, it would appear that the greatest factor, other than perhaps excessive muscular activity, in determining the water-vapor output of resting man is body temperature. It must be borne in mind, that in no instance in these experiments were the quantities of food appreciably more than enough for maintenance. The food was, generally, in the form of milk and similar products given in small amounts and at frequent periods throughout the day.

A comparison between the food experiments and the fasting experiments may also be made by noting the variations in the water-vapor elimination in the food experiment immediately following a fast. Thus, in comparing experiments Nos. 71 and 72, 73 and 74, and 75 and 76, such an inspection shows that, although the water-vapor output is by no means as large on the first day with food as on the first day of fast, it is in general somewhat greater than on the last day of fast. Thus, on the seventh day of experiment No. 75, the water-vapor output during the period from 7 a. m. to 9 a. m. was 55.1 grams and on the next day, namely, the first day of experiment No. 76, the output was 57.2 grams. On the seventh day of fasting for the second period it was

44.3 grams, and for the same period on the first day in experiment No. 76 it was 50.1 grams. A similar comparison holds for practically all the periods of the experiment, so that there is a slight positive increase in the elimination of water-vapor accompanying the ingestion of these small amounts of food. This may well be ascribed to the slight additional internal muscular activity called for on the ingestion of food.[180] A portion of the increase may also result from the rise in the respiration rate and the increased muscular activity as a whole indicated by the change in pulse rate.

Proportions of water-vapor eliminated from the lungs and skin.—The two chief opportunities for the vaporization of water are from the lungs and from the skin. Air taken into the lungs containing a varying amount of water-vapor is expelled saturated with water-vapor at the temperature of the body. The volume of air thus taken into the lungs and its relative humidity thus determines the total amount of water-vapor leaving the body in the expired air. The evaporation of water from the skin is not so directly measurable, since the quantity thus vaporized may show wide variations. The air in contact with the skin is certainly not saturated with water-vapor at the external temperature of the body. Furthermore, the clothing and the interlying air-spaces produce, so to speak, an artificial atmospheric environment. These air-spaces may contain widely varying amounts of water-vapor according to the thickness of the layer of air, the movements of the subject and the temperature of the air as well as the external temperature of the body. Many attempts have been made to measure directly the water-vapor expelled from the lungs. Such measurements, save for experiments of short duration, are impracticable.

The data obtained in the Middletown experiments give the total water of respiration and perspiration for each 2-hour period and for the day. By an indirect method of calculation, it is possible to apportion these amounts in such a manner as to estimate the amount exhaled from the lungs and thus show how the vaporization of water is divided between the lungs and skin. With this form of respiration apparatus, no direct measure of the actual ventilation of the lungs is at hand. Since, however, the amount of oxygen absorbed is accurately determined, it is possible to form a reasonably accurate estimate of the total ventilation of the lungs from the knowledge of the oxygen consumption. Zuntz[139] and his associates have found in a brilliant series of experiments that for every cubic centimeter of oxygen consumed by a man at rest, 21 cc. of air are inspired. Using this ratio, therefore, it is possible to compute the total ventilation of the lungs by multiplying the total oxygen consumption by 21.

[180] The marked difference in muscular activity in experiments Nos. 69 and 70 explains the one exception to the above comparisons.

[139] Höhenklima und Bergwanderungen in ihrer Wirkung auf den Menschen, N. Zuntz, A. Loewy, Franz Müller, W. Caspari (1906), Berlin, p. 380.

From the data recording the water determinations of the air residual in the chamber and the temperature of the air, the relative humidity is obtained and it is therefore possible to compute the total amount of water-vapor in the air taken into the lungs. Assuming that the air leaves the lungs saturated with water-vapor at the body temperature of 37°, the total amount of vapor in the expired air may thus be computed. Deducting the amount in the air inspired from that in the air expired, the water-vapor taken up by the air as it passes through the lungs is readily obtained.

The data are presented in table 220 herewith, in which the first column shows the total ventilation of the lungs, the second, the water in the inspired air, the third, the water in expired air, and the fourth the water eliminated from the lungs. If this last amount be deducted from the total water of respiration and perspiration, the water eliminated from the skin is obtained. This is recorded in column *e*. In the last two columns of the table the proportions of total water vaporized from the lungs and from the skin are given.

It will be seen that this method of computation involves two assumptions—first, that the total ventilation of the lungs is 21 times the volume of oxygen absorbed, and second, that the air leaving the lungs is saturated with water-vapor. Regarding the first of these assumptions, it is probably true that with certain individuals this factor may be wrong, but it is highly probable that in the large number of experiments here averaged the factor is reasonably correct. Regarding the second factor Rubner [111] has shown that with forced respiration during muscular work, the air leaving the mouth and nose may not be saturated with water-vapor at the temperature of the body. Recently Lesage [112] has, by means of a respiratory hygrometer, computed the water-content of the expired air from the dew point obtained by means of his apparatus. With ordinary respiration the tension of the water-vapor is found to be 36.9 mm. Since the expired air has a temperature of 36.5°, corresponding to a maximum tension of 43.1 mm., the author contends that the air is not saturated with water-vapor. While, therefore, this second assumption may be erroneous, for the want of more accurate data, it seems undesirable to make any correction for these values. If Lesage is correct, the result will be to lower the estimated amounts of water-vapor eliminated from the lungs.

The amount of water-vapor eliminated from the lungs is in most instances somewhat less than that from the skin. In some experiments, notably in experiment No. 80, it is but 30 per cent of the total water elimination, while in other experiments, for example, food experiment No. 74, it is over 50 per cent. Marked differences are noted between different subjects, especially in the longer experiments. In the series of 2-day experiments, these differences, aside from experiment No. 80, practically disappear.

[111] See discussion by Magnus-Levy, Physiologie des Stoffwechsels (1905), p. 426.
[112] Compt. rend. 136, 1097.

While with food experiment No. 70, the proportion of water eliminated from the lungs is somewhat less than during fasting, with experiments Nos. 72, 74, and 76, very little, if any, difference is noted. On the average, about 44 per cent of the water vaporized from the body of a resting man during fasting is from the lungs.

TABLE 220.—*Proportion of total water of respiration and perspiration eliminated from the lungs and skin, respectively, in metabolism experiments with and without food.*

Experiment number.	Subject and date.	(a) Total ventilation of lungs.	(b) Water in air inspired.	(c) Water in air expired.	(d) Water eliminated from lungs (c−b).	(e) Water eliminated from skin (f−d).	(f) Water eliminated from lungs and skin.	Proportion of water eliminated. (g) From lungs (d+f).	(h) From skin (e+f).
		Liters.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*P.ct.*	*P.ct.*
59......	B. F. D.:								
	Dec. 18–19, 1903......	9,253	74.30	402.18	327.88	654.44	982.32	33.4	66.6
	Dec. 19–20, 1903......	9,250	70.30	402.05	331.75	620.20	951.95	34.8	65.2
	Dec. 20–21, 1903......	9,498	70.76	412.83	342.07	601.08	943.15	36.3	63.7
68......	A. L. L.:								
	Apr. 27–28, 1904......	9,408	79.03	408.92	329.89	415.42	745.31	44.3	55.7
	Apr. 28–29, 1904......	9,446	78.87	410.57	331.70	429.04	760.74	43.6	56.4
69......	A. L. L.:								
	Dec. 16–17, 1904......	8,588	66.13	373.28	307.15	431.19	738.34	41.6	58.4
	Dec. 17–18, 1904......	9,493	83.73	412.61	328.88	569.48	898.36	36.6	63.4
	Dec. 18–19, 1904......	9,106	74.85	395.79	320.94	473.99	794.93	40.4	59.6
	Dec. 19–20, 1904......	8,838	66.11	384.14	318.03	409.92	727.95	43.7	56.3
70......	A. L. L.:								
	Dec. 20–21, 1904......	9,149	70.45	397.66	327.21	513.09	840.30	38.9	61.1
	Dec. 21–22, 1904......	9,867	81.11	428.87	347.76	655.02	1002.78	34.7	65.3
	Dec. 22–23, 1904......	10,773	93.08	468.25	375.17	683.90	1059.07	35.4	64.6
71......	S. A. B.:								
	Jan. 7– 8, 1905......	8,660	66.68	376.41	309.73	435.11	744.84	41.6	58.4
	Jan. 8– 9, 1905......	8,146	51.08	354.07	302.99	362.20	665.19	45.5	54.5
	Jan. 9–10, 1905......	7,908	45.31	343.72	298.41	269.25	567.66	52.6	47.4
	Jan. 10–11, 1905......	7,244	38.18	314.86	276.68	240.98	517.66	53.4	46.6
72......	S. A. B.:								
	Jan. 11–12, 1905......	7,598	41.64	330.25	288.61	256.23	544.84	53.0	47.0
73......	S. A. B.:								
	Jan. 28–29, 1905......	8,000	49.68	347.72	298.04	386.18	684.22	43.6	56.4
	Jan. 29–30, 1905......	8,054	43.33	350.07	306.74	329.31	636.05	48.2	51.8
	Jan. 30–31, 1905......	7,836	41.45	340.59	299.14	303.17	602.31	49.7	50.3
	Jan. 31–Feb. 1, 1905..	7,889	36.65	321.16	284.51	284.66	569.17	50.0	50.0
	Feb. 1– 2, 1905......	7,137	34.11	310.21	276.10	267.24	543.34	50.8	49.2
74......	S. A. B.:								
	Feb. 2– 3, 1905......	7,529	38.70	327.25	288.55	296.33	584.88	49.3	50.7
	Feb. 3– 4, 1905......	7,191	35.31	312.56	277.25	250.36	527.61	52.5	47.5
	Feb. 4– 5, 1905......	7,275	36.88	316.21	279.33	245.55	524.88	53.2	46.8
75......	S. A. B.:								
	Mar. 4– 5, 1905......	7,844	43.38	340.94	297.56	352.55	650.11	45.8	54.2
	Mar. 5– 6, 1905......	7,854	38.96	341.37	302.41	339.68	642.09	47.1	52.9
	Mar. 6– 7, 1905	7,875	39.61	342.29	302.68	355.16	657.84	46.0	54.0
	Mar. 7– 8, 1905......	7,637	35.59	331.94	296.35	299.78	596.13	49.7	50.3
	Mar. 8– 9, 1905......	7,218	32.68	313.78	281.10	298.19	579.29	48.5	51.5
	Mar. 9–10, 1905......	6,851	28.64	297.78	269.14	272.76	541.90	49.7	50.3
	Mar. 10–11, 1905......	6,856	29.48	298.00	268.52	274.33	542.85	49.5	50.5

TABLE 220.—*Proportion of total water of respiration and perspiration eliminated from the lungs and skin, respectively, in metabolism experiments with and without food.*—Continued.

Experiment number.	Subject and date.	(a) Total ventilation of lungs.	(b) Water in air inspired.	(c) Water in air expired.	(d) Water eliminated from lungs (c−b).	(e) Water eliminated from skin (f−d).	(f) Water eliminated from lungs and skin.	Proportion of water eliminated. (g) From lungs (d÷f).	(h) From skin (e÷f).
76......	S. A. B.:	*Liters.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*P. ct.*	*P. ct.*
	Mar. 11–12, 1905......	7,751	36.12	336.90	300.78	316.03	616.81	48.8	51.2
	Mar. 12–13, 1905......	7,353	33.38	319.60	286.22	296.08	582.30	49.2	50.8
	Mar. 13–14, 1905......	7,454	33.92	323.99	290.07	321.32	611.39	47.4	52.6
77......	S. A. B.:								
	Apr. 8– 9, 1905......	8,174	42.67	355.28	312.61	357.00	669.61	46.7	53.3
	Apr. 9–10, 1905......	8,402	44.19	365.19	321.00	316.73	637.73	50.3	49.7
	Apr. 10–11, 1905......	7,802	40.34	339.11	298.77	318.75	617.52	48.4	51.6
	Apr. 11–12, 1905......	7,814	39.70	339.64	299.94	326.62	626.56	47.9	52.1
79......	H. E. S.:								
	Oct. 13–14, 1905......	8,466	82.63	367.97	285.34	381.64	666.98	42.8	57.2
	Oct. 14–15, 1905......	8,898	93.25	386.75	293.50	410.57	704.07	41.7	58.3
80......	C. R. Y.:								
	Oct. 27–28, 1905......	8,471	75.14	368.19	293.05	633.71	926.76	31.6	68.4
	Oct. 28–29, 1905......	9,240	85.38	401.62	316.24	744.29	1060.53	29.8	70.2
81......	A. H. M.:								
	Nov. 21–22, 1905......	7,597	39.81	330.20	290.39	318.20	608.59	47.7	52.3
	Nov. 22–23, 1905......	7,748	41.37	336.77	295.40	375.34	670.74	44.0	56.0
82......	H. C. K.:								
	Nov. 24–25, 1905......	9,750	64.74	423.78	359.04	483.06	842.10	42.6	57.4
	Nov. 25–26, 1905......	10,787	76.05	468.86	392.81	547.69	940.50	41.8	58.2
83......	H. R. D.:								
	Dec. 5– 6, 1905......	8,603	49.30	373.93	324.63	359.89	684.52	47.4	52.6
	Dec. 6– 7, 1905......	8,150	44.91	354.24	309.33	362.68	672.01	46.0	54.0
85......	N. M. P.:								
	Dec. 9–10, 1905......	9,225	56.18	400.96	344.78	431.01	775.79	44.4	55.6
	Dec. 10–11, 1905......	9,931	68.13	431.65	363.52	449.91	813.43	44.7	55.3
89......	D. W.:								
	Jan. 10–11, 1906......	9,487	62.99	402.35	349.36	470.21	819.57	42.6	57.4
	Jan. 11–12, 1906......	10,015	66.50	435.30	368.80	433.94	802.74	45.9	54.1

CARBON DIOXIDE ELIMINATION.

Carbon dioxide is the end product of oxidation of all carbonaceous material, aside from those fragments of the proteid molecule that are excreted in the urine. A measure of the carbon dioxide production furnishes, therefore, an estimate of total katabolism that has been of great value.

From the earliest experiments of Lavoisier,[113] Davy,[114] and Allen & Pepys,[115] the importance of carbon dioxide in the respiratory gases has been emphasized.

[113] Mémoires de l'Académie des Sciences, Paris, 1789, Œuvres de Lavoisier, 2, p. 695. Cited by R. Tigerstedt, Die Physiologie des Stoffwechsels, Nagels Handbuch der Physiologie des Menschen (1905), p. 337.

[114] "Researches," p. 431.

[115] Philosophical Transactions (1808), p. 250.

The inaccuracies in the determination of the water of respiration and perspiration and in the method for determining the total nitrogen of the urine and the deficiency in the measurements of oxygen and heat production in the majority of the earlier experiments, are in part at least compensated by reasonably accurate determinations of carbon dioxide. The comparison, therefore, of the results obtained by different investigators of the carbon dioxide production of fasting men is very much more satisfactory than that of any factor thus far considered in this report.

The quantitative experiments of Scharling,[116] Andral & Gavarret,[117] Brunner & Valentin[118] gave us at an early date much information regarding the carbon dioxide output of different individuals for short periods, and the rapid advancement in the technique of studying the respiratory gases, which followed upon the successful experiments of Speck,[119] Zuntz & Geppert,[120] Chauveau & Tissot,[121] and more recently Magnus-Levy,[122] Loewy,[123] and Durig,[124] leaves but little to be considered regarding the carbon dioxide elimination under normal conditions, so far as short periods are concerned.

Many of these experimenters recognized the importance of determining the carbon dioxide output during inanition, and indeed in the large number of experiments on the effect of muscular work on metabolism, the "base line" may be said to be the value for carbon dioxide production after a short fast. In the very large majority of these experiments, the elimination of this gas was determined for only short periods, rarely an hour, and the length of the fast was seldom over 12 hours. While these results have a definite value for the specific purpose for which the experiments were conducted, they are much less valuable as an indication of the carbon production of fasting man during 24 hours.

The Zuntz-Geppert apparatus has been used for a number of observations on fasting man during short respiration experiments. Zuntz (7) and associates, in whose hands the method has reached the greatest degree of perfection, made a number of observations on the two fasting men, Cetti and Breithaupt. These observations were confined to short periods, 10 to 20 minutes, of each fasting day. The subjects were lying on a sofa and accordingly the carbon dioxide output represents the elimination during complete rest. In certain

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[116] Ann. der Chem. und Pharm. (1843), 45, p. 214.

[117] Ann. de Chim. et de Phys. (1843), Ser. 3, 8, p. 129.

[118] Medicinische Vierteljahreschrift Archiv f. physiol. Heilk. von Roser und Wunderlich (1843), 2, p. 373. Abstracted in Pharm. Centrbl. (1843), 14, p. 765.

[119] Schriften zur Beförderung der gesammten Naturwissenschaften zur Marburg (1871), 10.

[120] Archiv f. d. ges. Physiol. (1888), 42, p. 189.

[121] Comptes rendus (1899), 129, p. 249.

[122] Loc. cit.

[123] Archiv f. d. ges. Physiologie (1888), 42, p. 268.

[124] Loc. cit.

of the experiments with Breithaupt, observations were likewise made during work. From the data obtained during these short experiments, the authors computed the total carbon dioxide output of these fasting men.

The daily total elimination for the 10 days of Cetti's fast was estimated to be 567, 501, 482, 478, 470, 467, 502, 526, 489, and 449 grams, respectively. A cold on the second day and intestinal irritation on the third and fourth days of Breithaupt's fast so invalidated the results for the short periods that the authors did not attempt to compute the 24-hour output from the data obtained. In a subsequent discussion of results, the authors recognized the fact that the observations were made during a period when bodily activity was at a minimum, and consequently the results obtained by computation were arbitrarily increased by one-fifth, in an attempt to approximate the probable increase of carbon dioxide during periods of ordinary muscular activity. The carbon dioxide production thus measured was the basis of the calculations for water of respiration and perspiration.

Hanriot & Richet,[125] with a different form of respiration apparatus, determined the carbon dioxide output of a man weighing 50 kilograms who fasted for 46 hours. The amounts liberated per hour were 15.3, 14.15, 14.30, and 14.35 liters after the seventeenth, twenty-fourth, twenty-ninth, and forty-sixth hours of the fast. The authors did not compute the output per 24 hours from these short experiments, but concluded from the results obtained that at the end of a few hours of complete fasting, the respiratory exchange becomes constant.

Luciani (4) attempted during the Florence fast to determine the carbon dioxide elimination of Succi. The experiments were all of short duration and the method and results have been criticised by Zuntz (7). According to Luciani's results the total output of carbon dioxide on the day before the fast was 479 grams and on the tenth, twentieth, and twenty-ninth fasting days 435, 406, and 387 grams, respectively.

Experiments in which the carbon dioxide production of fasting men was determined during the major part of the 24 hours were first made by Ranke.[126] Ranke made 3 fasting experiments on himself, in the Pettenkofer respiration apparatus, and as has been pointed out before, these were the first experiments made with this historic apparatus. The length of the periods was 24 hours. One experiment, at least, represented the second day of fasting, since the subject had already fasted 24 hours. In reporting the results, the author states that he found after the experiments were made that the apparatus gave results somewhat too high. Accordingly, he assumed an average carbon dioxide production of 663 grams (180.85 grams of carbon) for the 3 fasting days.

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[125] Comptes Rendus (1888), 106, p. 496.
[126] Archiv Anat. u. Physiol. (1862), p. 340.

The next series of experiments on the total carbon dioxide output of fasting men was made by Pettenkofer & Voit.[137] In two 24-hour experiments when the man was at rest, the elimination of carbon dioxide as measured in the Pettenkofer apparatus was 738 and 729 grams for 24 hours. During a third 24-hour fasting experiment the subject performed considerable muscular work and the carbon dioxide production increased to 1187.5 grams.

Sadovyen (2), with the Pashutin respiration apparatus, measured the carbon dioxide elimination of a fasting man in two experiments, one of 2 days and the other 4 days. In this series of experiments, the subject did not remain in the chamber during the entire 24 hours, the experimental periods being generally of 9 to 10 hours' duration. No water was consumed during the first experiment. The total carbon dioxide production for the 2 days was 755 and 746 grams, respectively, and for the 4 days of the second experiment the amounts, computed on the basis of 24 hours, were 810, 795, 620, and 613 grams, respectively.

In studying the production of heat of a healthy man in a condition of comparative rest, Likhachev[138] included a study of the carbon dioxide output of man during inanition. The subject remained inside the Pashutin respiration apparatus for over 24 hours and the records for the day were therefore unbroken. The amount of carbon dioxide produced during this experimental day was 596 grams or 10.7 grams per kilo of body weight.

The carbon dioxide production of the fasting subject J. A. (9) was determined by means of the Tigerstedt respiration apparatus. As in the experiments of Sadovyen, the subject did not remain within the chamber continuously, but spent about two hours each day outside. Computed on the basis of 24 hours, the carbon dioxide elimination measured by the apparatus was on the 5 days 691, 658, 632, 621, and 608 grams, respectively.

The fasting experiments made in this laboratory and previously reported[139] included determinations of the carbon dioxide. During experiments Nos. 36, 39, and 42, each of 24 hours' duration, the production was 711, 649, and 620 grams, respectively. The amounts eliminated for the 2 days of experiment No. 51 were 703 and 698 grams, respectively.

Since the production of carbon dioxide and the metabolic activity are, in general, largely proportional to the body-weight, these older experiments may perhaps be better compared by noting the amounts of carbon dioxide per kilogram of body-weight and per square meter of body surface. The total carbon dioxide production for the older experiments is given in table 221, together with the amounts per kilo of body-weight and per square meter of body surface.

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[137] Zeit. f. Biologie (1866), 2, p. 478.
[138] Dissertation (Russian), 1893, St. Petersburg.
[139] U. S. Dept. of Agr., Office of Expt. Sta. Bul. 136.

TABLE 221.—*Carbon dioxide production of fasting men, at rest.*

Investigators.	Day of fast.	Body weight.	Carbon dioxide per 24 hours. Total.	Per kilo of body-weight.	Per square meter of body surface.[1]
		Kilos.	*Grams.*	*Grams.*	*Grams.*
Ranke		71.9	[2]663	9.2	311
Pettenkofer & Voit	First	70.0	738	10.5	353
	Second	70.0	729	10.4	349
Sadovyen:					
I	First	79.4	755	9.5	332
	Second	77.7	746	9.6	333
II	First	80.2	810	10.1	354
	Second	78.8	795	10.1	351
	Third	77.6	620	8.0	277
	Fourth	76.7	613	8.0	276
Likhachev		55.8	596	10.7	332
Johannson, Landergren, Sondén & Tigerstedt	First	67.0	691	10.3	340
	Second	65.7	658	10.0	328
	Third	64.9	632	9.7	318
	Fourth	64.0	621	9.7	315
	Fifth	63.1	608	9.6	312
[3]Atwater and Benedict and associates:					
No. 36[4]		74.7	711	9.5	326
No. 39[4]		72.9	649	8.9	302
No. 42[4]		76.4	620	8.1	280
No. 51	First	79.1	703	8.9	310
	Second	78.1	698	8.9	310

[1] In computing body surface the formula of Meeh has been used: $12.312 \sqrt[3]{\text{body-weight}^2}$.
[2] Average of 3 days.
[3] U. S. Dep. Agr., Office of Experiment Stations, Bul. 136.
[4] Experiments of one day's duration.

Although there were wide variations in body-weight of the subjects of the experiments shown in this table, the amount of carbon dioxide per kilo of body-weight eliminated per 24 hours is not far from 9.5 grams, and per square meter of body surface about 320 grams. Little value can be placed upon the regularity or irregularity of results obtained by methods differing as widely as these, but as was pointed out above, in all probability the determination of carbon dioxide was reasonably accurate in all the experiments, and the variations appearing in the different amounts are probably due to muscular activity more than to any other factor. Indeed, when reduced to per kilo of body-weight and per square meter of body surface, the results show, even in experiments with the same subject, variations that can seemingly be explained in no way save by differences in muscular activity. The influence of an increase in muscular activity on the carbon dioxide production may well account for the slight differences here observed, even in experiments generally designated as rest experiments.

In all the fasting experiments recently made in the laboratory of Wesleyan University and here reported, the carbon dioxide was determined not only for the 24 hours but for each 2- or 3-hour period throughout the experiments. The details of the determinations for the shorter periods are given in connection with the statistical tables in the preceding section. The total quantities of carbon dioxide eliminated per day are shown in table 222.

TABLE 222.—*Carbon dioxide eliminated in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59...	B.F.D., Dec. 18 to 20, 1903....	670.6	658.9	650.2	....	....	....	....
68...	A.L.L., Apr. 27 to 28, 1904....	694.4	679.8	....	....	....	....	....
69...	A.L.L., Dec. 16 to 19, 1904....	631.8	666.4	640.7	612.6	....	....	....
71...	S.A.B., Jan. 7 to 10, 1905....	669.0	570.2	554.0	508.1	....	....	....
73...	S.A.B., Jan. 28 to Feb. 1, 1905.	608.9	560.0	541.7	515.2	482.0	....	...
75...	S.A.B., Mar. 4 to 10, 1905....	569.9	550.6	545.1	534.2	496.4	477.4	475.6
77...	S.A.B., Apr. 8 to 11, 1905....	599.5	576.9	556.6	544.8	....	....	....
79...	H.E.S., Oct. 13 to 14, 1905....	632.0	635.2	....	....	....	....	....
80...	C.R.Y., Oct. 27 to 28, 1905....	627.4	640.8	....	....	....	....	....
81...	A.H.M., Nov. 21 to 22, 1905....	534.7	524.3	....	...	....	....	....
82...	H.C.K., Nov. 24 to 25, 1905....	740.9	767.3	....	....	....	....	....
83...	H.R.D., Dec. 5 to 6, 1905....	606.7	579.2	....	....	....	....	....
85...	N.M.P., Dec. 9 to 10, 1905....	696.6	719.3	....	....	....	....	....
89...	D. W., Jan. 10 to 11, 1906....	722.4	705.5	....	....	....	....	....
	Average	643.2	631.0	581.4	543.0	489.2	477.4	475.6

Considerable variations occur in the amounts of carbon dioxide produced on the different fasting days of these experiments. As the fast progresses, the amounts eliminated generally become less and less. The total amounts for the first day of fasting varied from 535 grams in experiment No. 81 to 741 grams in experiment No. 82, the average on the first day for the 14 experiments being 643 grams. On the second day the fluctuations are even greater, the smallest amount (524 grams) being measured in experiment No. 81, the largest, in experiment No. 82 (767 grams). The average for the second day in the 14 experiments is 631 grams. The much smaller number of experiments which continued 3 days affects in marked degree the average for the third day, which diminishes to 581 grams. The variations range from 542 to 650 grams. The variations on the fourth day range from 508 to 613, the average being 543 grams. The carbon dioxide production in experiments Nos. 73 and 75 was nearly identical on the fifth day. The average, 489 grams, is somewhat higher than the amounts excreted on the sixth and seventh days of experiment No. 75.

If the longer experiments with S. A. B. be examined more specifically, it will be found that the carbon dioxide elimination decreased regularly in all cases as the fast progressed.

There are two causes for the variations in the output of carbon dioxide on the different days of the experiments: first, differences in the body-weights of the subjects, and second, variations in their muscular activity. It is customary, in comparing experiments of this nature, to compute the carbon dioxide production per kilo of body-weight or per square meter of body surface. Since these values are given separate treatment later in the report, the table showing the computation is reserved for that discussion, attempt there being made to reduce the carbon dioxide output not only to constant body-weight and body surface, but also during periods of approximately constant bodily activity, namely, during the period of sleep at night.

RELATION OF CARBON IN URINE TO TOTAL CARBON.

Carbon is excreted from the body in two forms—carbon dioxide of the respiratory gases and the carbon of organic matter of the urine. To these should be added, in experiments in which food is taken, the carbon excreted in the feces, but as explained elsewhere (see p. 120) the feces are not considered in the fasting experiments. For computing the losses of body material during fasting, the amount of carbon in the urine is of importance, and hence the amounts for these experiments have been computed and recorded in table 223.

The proportion of total carbon excreted in the urine is of interest, since in many of the earlier experiments, the actual amounts of the carbon in the urine have not been determined, the assumption being made that the carbon excreted in this manner is but a small proportion of the total. The per cent of total carbon in the urine is given in the last column of the table.

The total carbon elimination varies practically with the carbon dioxide production. The smallest excretion found during any fasting day is on the fifth day of experiment No. 73, 139.4 grams; the largest recorded amount is on the second day of experiment No. 82, 220.0 grams. The average daily amount for all experiments is 174.3 grams.

As was pointed out in a discussion of the quantities of carbon in the urine, there are wide variations in the amounts from day to day, the largest elimination occurring as a rule, in the later days of the fast. This is especially noticeable in the case of experiment No. 77, where as high as 14.6 grams of carbon appeared in the urine on a single day. An examination of the table shows that the carbon of the urine tends to increase as the fast progresses, while the total carbon frequently decreases. Hence, the proportion of total carbon which appears in the urine varies considerably. The lowest per cent is found on the first day of experiment No. 71, namely, 2.8, and the highest on the last day of experiment No. 77, namely, 8.9. The daily average of all experiments without food is 5.5.

TABLE 223.—*Relation of carbon excreted in urine to total carbon eliminated in metabolism experiments without food.*

Experiment number.	Subject and date.	Carbon in urine.	Total carbon eliminated.	Proportion of total carbon in urine.
		Gms.	*Gms.*	*Per ct.*
59..	B.F.D., 1903:			
	Dec. 18–19....	8.7	191.6	4.6
	Dec. 19–20....	10.4	190.1	5.5
	Dec. 20–21....	10.9	188.2	5.8
	Total, 3 days.	30.0	569.9	....
	Av. per day..	10.0	190.0	5.3
68..	A.L.L., 1904:			
	Apr. 27–28....	9.7	199.1	4.9
	Apr. 28–29....	10.4	195.6	5.3
	Total, 2 days.	20.1	394.7	....
	Av. per day..	10.1	197.4	5.1
69..	A.L.L., 1904:			
	Dec. 16–17....	8.3	180.6	4.6
	Dec. 17–18....	10.0	191.7	5.2
	Dec. 18–19....	10.4	185.1	5.6
	Dec. 19–20....	9.4	176.5	5.3
	Total, 4 days.	38.1	733.9	....
	Av. per day..	9.5	183.5	5.2
71..	S.A.B., 1905:			
	Jan. 7– 8....	5.2	187.7	2.8
	Jan. 8– 9....	8.3	163.8	5.1
	Jan. 9–10....	8.7	159.7	5.4
	Jan. 10–11....	7.7	146.3	5.3
	Total, 4 days.	29.9	657.5	....
	Av. per day..	7.5	164.4	4.5
73..	S.A.B., 1905:			
	Jan. 28–29....	7.5	173.5	4.3
	Jan. 29–30....	8.3	161.0	5.2
	Jan. 30–31....	7.9	155.7	5.1
	Jan. 31–Feb. 1.	7.7	148.2	5.2
	Feb. 1–2......	7.9	139.4	5.7
	Total, 5 days.	39.3	777.8	....
	Av. per day..	7.9	155.6	5.1
75..	S.A.B., 1905:			
	Mar. 4– 5....	8.1	163.6	5.0
	Mar. 5– 6....	11.5	161.7	7.1
	Mar. 6– 7....	11.1	159.8	7.0
	Mar. 7– 8....	12.2	157.9	7.7
	Mar. 8– 9....	12.7	148.0	8.6
	Mar. 9–10....	12.0	142.2	8.5
	Mar. 10–11....	11.3	141.0	8.0
	Total, 7 days.	78.9	1074.2	....
	Av. per day..	11.3	153.5	7.4
77..	S.A.B., 1905:			
	Apr. 8– 9....	8.0	171.5	4.7
	Apr. 9–10....	13.9	171.3	8.1
	Apr. 10–11....	13.7	165.5	8.3
	Apr. 11–12....	14.6	163.1	8.9
	Total, 4 days.	50.2	671.4	....
	Av. per day..	12.5	167.8	7.5
79..	H.E.S., 1905:			
	Oct. 13–14....	6.3	178.6	3.5
	Oct. 14–15....	10.2	183.5	5.6
	Total, 2 days.	16.5	362.1	....
	Av. per day..	8.2	181.1	4.6
80..	C.R.Y., 1905:			
	Oct. 27–28....	7.1	178.2	4.0
	Oct. 28–29....	9.0	183.7	4.9
	Total, 2 days.	16.1	361.9	....
	Av. per day..	8.1	180.9	4.5
81..	A.H.M., 1905:			
	Nov. 21–22....	7.5	153.3	4.9
	Nov. 22–23....	9.5	152.5	6.2
	Total, 2 days.	17.0	305.8	....
	Av. per day.	8.5	152.9	5.6
82..	H.C.K., 1905:			
	Nov. 24–25....	7.7	209.8	3.7
	Nov. 25–26....	10.8	220.0	4.9
	Total, 2 days.	18.5	429.8	....
	Av. per day..	9.2	214.9	4.3
83..	H.R.D., 1905:			
	Dec. 5–6......	9.7	175.2	5.6
	Dec. 6–7......	12.8	170.7	7.5
	Total, 2 days.	22.5	345.9	....
	Av. per day..	11.3	173.0	6.5
85..	N.M.P., 1905:			
	Dec. 9–10....	7.7	197.7	3.9
	Dec. 10–11....	8.2	204.4	4.0
	Total, 2 days.	15.9	402.1	....
	Av. per day..	8.0	201.0	4.0
89..	D.W., 1906:			
	Jan. 10–11....	8.4	205.4	4.1
	Jan. 11–12....	9.9	202.3	4.9
	Total, 2 days.	18.3	407.7	....
	Av. per day..	9.1	203.9	4.5
	Av. of experiments without food....	9.6	174.8	5.5

The errors involved in the determination of carbon in the urine have been discussed previously, and even if a gross error of 5 per cent be assumed, the effect on the total carbon excretion is seen to be extremely small, and hence it is obvious that considerable errors in the determination of the carbon in the urine are practically without effect on the total carbon elimination in ordinary metabolism experiments.

Carbon in the urine, feces, and respiratory products was determined in the 5-day fasting experiment with J. A. (9). There were found 8.0, 8.3, 9.9, 10.3, and 9.3 grams of carbon in the urine, while the corresponding amounts of carbon in the respiration were 188.5, 179.4, 172.2, 169.4, and 165.8 grams. Computed on the basis of the total carbon elimination, the percentages of carbon in the urine for the 5 days were 4.1, 4.5, 5.4, 5.7, and 5.3, respectively.

The general conclusion can, therefore, be made that with fasting man at rest, the carbon of the urine is about 5 per cent of the total carbon excretion.

OXYGEN CONSUMPTION.

Since the classic experiments of Lavoisier showing the relation between oxygen consumption and vital processes, the direct measurement of oxygen in the respiratory gases has not been attempted, save in one or two cases. Although as Lusk[180] points out there is no record of the method employed by Lavoisier in obtaining his results, it is remarkable how closely his statements of the quantities of oxygen consumed by resting man agree with the measurements by modern methods.

In the earlier experiments with the Pettenkofer respiration apparatus, in which the attempt was made to determine accurately the water vaporized, estimations of the amount of oxygen were attempted by computations based on the gains or losses of body weight, carbon dioxide excretion, and water-vapor elimination. When the errors involved in the determination of water-vapor are taken into consideration, it is seen that whatever approach to accuracy the oxygen estimations appear to have, it must have been the resultant of a number of more or less compensating errors.

An attempt was made in the more accurate experiments of Sadovyen (2), in which the amounts of carbon dioxide and water-vapor were determined for a great part of each day, to measure by the indirect method the amount of oxygen consumed. On the 2 days of the fasting experiment with man in which no water was consumed, the oxygen intake was estimated to be 1081 and 1010 grams, respectively. The oxygen consumption during the 4-day experiment, in which water but no food was taken, was estimated to be 746, 921, 698, and 943 grams for the different days.

Similarly Likhachev[181] estimated indirectly the amount of oxygen consumed during a 1-day fast to be 596 grams, or 11.9 grams per kilo of body-weight.

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[180] Elements of the Science of Nutrition, Philadelphia (1906), p. 18.
[181] Loc. cit.

With the development of the type of respiratory apparatus brought to such signal success by Zuntz and associates, innumerable experiments have been made in which the respiratory quotient has been determined during brief fasts. It is true of the oxygen as of the carbon dioxide, that the determinations of the fasting values are of importance in the interpretation of the respiratory quotient in the large majority of experiments. This type of apparatus was used in determining the oxygen intake of the fasting subjects Cetti and Breithaupt (7). Although results were obtained for but a few minutes each day and during the respiration experiment the subject was lying on a sofa, the authors computed the total oxygen consumption for the 24 hours on the basis of these short experiments. The amounts of oxygen consumed for the 10 days of Cetti's fast were 567, 501, 482, 478, 470, 467, 502, 526, 489, and 449 grams, respectively. These values are obtained by multiplying the quantity of oxygen absorbed per minute during rest by the total number of minutes in the day and no allowance is made for the variations in muscular activity, so that the values can at best be only approximate. In the experiments on Breithaupt, the complications of a cold and other disturbances were so noticeable that the authors did not consider the computed results for the 24 hours as of general value.

Hanriot & Richet,[132] using a different form of respiration apparatus, determined the oxygen consumption of a fasting man after 46 hours of fasting. The amounts consumed per hour after the seventeenth, twenty-fourth, twenty-ninth, and forty-sixth hours of the fast were 17.04, 16.85, 16.05, and 16.90 liters, respectively. The subject of the experiment weighed 50 kilograms. These observations were likewise made only during short periods.

The first direct determinations of oxygen consumed by man during 24 hours are those made with the Hoppe-Seyler[133] modification of the Regnault and Reiset apparatus, although none of the experiments reported as made in this apparatus were fasting experiments.

Zuntz has recently devised an apparatus on the Regnault and Reiset plan that can be used for small animals or infants.[134] No experiments with infants have, however, as yet been reported.

Direct determinations of the amount of oxygen consumed by man have been made in a number of experiments in this laboratory during the past 3 years. A brief preliminary report of one of these experiments[135] has been followed by a more detailed discussion of one day of an experiment with this

[132] Compt. rend. de l'Académie des Sciences (1888), 106, p. 496.

[133] Zeit. f. physiol. Chemie (1894), 19, p. 574.

[134] Archiv f. Physiol. (Physiol. Abth. d. Archiv f. Anat. u. Physiol.) (1905), Supplement, Band, p. 431.

[135] A respiration calorimeter with appliances for the direct determination of oxygen, 24 pages. Wesleyan University, Middletown, Connecticut. Printed, not published, Aug., 1903, W. O. Atwater & F. G. Benedict.

apparatus,[186] and the results of a series of experiments covering 24 days have been recently published.[187]

So far as we are aware, the first determinations of the oxygen consumption of fasting man are reported herewith. The method has been considered in brief in the introductory section of this report and in detail elsewhere.[188] The accuracy of these measurements has also received special treatment. In brief, it may be said that for experiments of 24 hours or longer the results are extremely satisfactory. For 2-hour periods the oxygen determinations are satisfactory only when there is like muscular activity at the beginning and end of the period, since constancy in the average temperature of the air residual in the chamber is of the utmost importance in securing accurate oxygen measurements.[189]

The detailed data regarding oxygen during the 2-hour periods of the fasting experiments are given in the statistical data in the preceding section. The total amounts of oxygen consumed during each 24 hours are shown in the following table:

TABLE 224.—*Oxygen consumed in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59...	B.F.D., Dec. 18 to 20, 1903....	629.4	629.2	646.1	....	....	....	....
68...	A.L.L., Apr. 27 to 28, 1904....	640.0	642.6	....	....	....	....	....
69...	A.L.L., Dec. 16 to 19, 1904....	584.2	645.8	619.4	601.2	....	....	....
71...	S.A.B., Jan. 7 to 10, 1905....	589.1	554.1	538.0	492.7	....	....	....
73...	S.A.B., Jan. 28 to Feb. 1, 1905.	544.2	547.9	533.0	502.7	485.5	....	....
75...	S.A.B., Mar. 4 to 10, 1905....	533.6	534.3	535.7	519.5	491.0	466.1	466.4
77...	S.A.B., Apr. 8 to 11, 1905....	556.0	571.6	530.7	531.6	....	....	....
79...	H.E.S., Oct. 13 to 14, 1905....	575.9	605.3	....	....	....	....	....
80...	C.R.Y., Oct. 27 to 28, 1905....	576.2	628.6	....	....	....	....	....
81...	A.H.M., Nov. 21 to 22, 1905....	516.8	527.1	....	....	....	....	....
82...	H.C.K., Nov. 24 to 25, 1905....	663.3	733.8	....	....	....	....	....
83...	H.R.D., Dec. 5 to 6, 1905....	585.2	554.4	....	....	....	....	....
85...	N.M.P., Dec. 9 to 10, 1905....	627.5	675.6	....	....	....	....	....
89...	D.W., Jan. 10 to 11, 1906....	645.4	681.3	....	....	....	....	....
	Average	590.5	609.4	567.2	529.6	488.3	466.1	466.4

Table 224 shows that the total oxygen consumption during fasting may vary widely with different individuals. Thus, on the second day of experiment No. 82, 734 grams were absorbed, while on the sixth and seventh days of experiment No. 75, only 466 grams were consumed. The average for the first 2 days of fast is nearly the same, i. e., 591 and 609 grams. The amounts are

[186] Carnegie Institution of Washington Publication No. 42, p. 178.
[187] U. S. Dept. Agr., Office of Expt. Sta. Bul. 175 (1907).
[188] Carnegie Institution of Washington, Publication No. 42; U. S. Dept. Agr., Office of Expt. Sta. Bul. 175.
[189] For discussion of the errors affecting the oxygen determination see Office of Expt. Sta. Bul. 175, pp. 24-32.

larger on the second day of fasting than on the first day with but three exceptions, the increase being, in one instance, as much as 70 grams, and in another about 61 grams. In practically all cases the oxygen intake diminishes after the second day, reaching a constant, 466 grams, on the sixth and seventh days.

Considering experiments with the same individual, S. A. B., it is to be noted that even on the first day of fast, there are noticeable differences in the amounts consumed, which range from 534 grams in experiment No. 75, to 589 grams in experiment No. 71. The excessive amount in the latter case may, however, be explained, in part at least, by the fact that a 10-minute period of hard muscular exercise on the bicycle ergometer was taken on this day. A similar variation appears, however, between the amounts for the first day of experiments Nos. 68 and 69, made with the subject A. L. L.

Obviously, as was the case with the carbon dioxide elimination, differences in the bodily activity and body-weight of the subjects may explain in large part the variations in the amounts of oxygen consumed during the experiments, and indeed during different experiments with the same subject. The relations between the oxygen consumption, carbon dioxide excretion, heat production, and muscular activity are discussed in detail in a subsequent section. The discussion of the relations between the body-weight and the oxygen intake are also considered elsewhere.

RESPIRATORY QUOTIENT.

The ratio between the volumes of carbon dioxide excreted and oxygen consumed is of great value in indicating the nature of the material undergoing katabolism in the body. The combustion of the carbohydrate is accompanied by an absorption of oxygen which in the course of the oxidation results in the production of an equal volume of carbon dioxide. On the other hand, when fat is oxidized, the oxygen absorbed is used to oxidize not only the carbon of the fat, but also the organic hydrogen. While the combustion of the carbon results in the formation of an aeriform combustion product, carbon dioxide, oxidation of the hydrogen results in the formation of water-vapor which is not measured in the ordinary methods of studying the respiratory gases. Consequently, the volume of carbon dioxide excreted is less than that of the oxygen consumed. The ratio between the volumes of carbon dioxide and the oxygen is called the respiratory quotient. It is commonly expressed by the fraction $\frac{CO_2}{O_2}$. In the case of the carbohydrate, this respiratory quotient is equal to 1 since equal volumes of oxygen and carbon dioxide are involved in the respiratory exchange. The combustion of fats, on the other hand, results in a respiratory quotient which is always less than 1, and for the ordinary animal fats, it has been computed to be about 0.711.[140]

[140] For a more detailed discussion of the theoretical respiratory quotients to be derived from the combustion of different kinds of fats and carbohydrates, see U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

The computation of the theoretical respiratory quotient from the combustion of carbohydrate or fat is relatively simple, but the nature of the cleavage of the protein molecule and the excretion of partially oxidized material in the urine complicates the computation of the quotient resulting from the oxidation of protein. The value commonly accepted for protein is 0.809.

For further discussion of the theoretical factors involved in the computation of the theoretical respiratory quotients resulting from the combustion of protein see Magnus-Levy.[141]

While the theoretical consideration of the respiratory quotients to be derived from the combustion of the various nutrients in the body is capable of mathematical expression, considerable difficulty is experienced in interpreting the respiratory quotients actually determined on man. For, instead of the combustion of any given one of these ingredients of the body, protein, fat, or carbohydrate, there is in practically all cases a simultaneous combustion of the three. It has commonly been believed that in fasting experiments of short duration, the combustion is chiefly that of fat with a small amount of protein, and it has been maintained that the combustion of protein is relatively constant from hour to hour. Hence, in the studies made by Zuntz, Loewy, Magnus-Levy, and their associates, the quotient obtained during fasting has been taken as a measure of the respiratory quotient derived from the combustion of fat with a constant amount of protein. The various factors influencing the quotients, such as the ingestion of food, muscular exercise, etc., have been studied in the majority of the experiments made by these investigators, and the results obtained are, for the specific purpose for which they were designed, all that could be desired.

On the other hand, when the respiratory quotient is determined not only for the total 24 hours, but also for 2-hour periods, there may be, during the periods, a lack of uniformity in the amount and rapidity of the disintegration, not only of protein but likewise of carbohydrate, and, therefore, it is readily seen that the interpretation of quotients for 2-hour periods, even when correctly determined, is a matter of considerable complexity. Indeed, the use commonly made of the respiratory quotient is of but little value in complete metabolism experiments, and recourse must be had to the more complete apportionment of the oxidation among the three principal ingredients of the body—protein, fat, and carbohydrate—according to the method elaborated and discussed in connection with the statistical data of experiment No. 59 (p. 36).

The respiratory quotients for each day, as determined in these experiments, are of decided general interest judged from the standpoint of the observations of other investigators, and accordingly they are here presented in table 225.

[141] Physiologie des Stoffwechsels (1905), p. 217; also Zeit. f. klin. med. (1906), 60, Heft. 3, p. 1.

TABLE 225.—*Respiratory quotients for 24 hours in metabolism experiments without food.*

Experiment number.	Subject and date.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
59...	B.F.D., Dec. 18 to 20, 1903....	0.78	0.76	0.73	....	....	....	....
68...	A.L.L., Apr. 27 to 28, 1904....	.79	.77	....	....	....	....	....
69...	A.L.L., Dec. 16 to 19, 1904....	.79	.75	.75	0.74	....	....	....
71...	S.A.B., Jan. 7 to 10, 1905 ...	.83	.75	.75	.75	....	....	....
73...	S.A.B., Jan. 28 to Feb. 1, 1905.	.81	.74	.74	.75	0.72	....	...
75...	S.A.B., Mar. 4 to 10, 1905....	.78	.75	.74	.75	.74	0.75	0.74
77...	S.A.B., Apr. 8 to 11, 1905....	.78	.73	.76	.75	....	....	....
79...	H.E.S., Oct. 13 to 14, 1905....	.80	.76	....	....	....	....	....
80...	C.R.Y., Oct. 27 to 28, 1905....	.79	.74	....	....	....	....	....
81...	A.H.M., Nov. 21 to 22, 1905....	.75	.72	....	....	....	....	....
82...	H.C.K., Nov. 24 to 25, 1905....	.81	.76	....	....	....	....	....
83...	H.R.D., Dec. 5 to 6, 1905....	.75	.76	....	....	....	....	....
85...	N.M.P., Dec. 9 to 10, 1905....	.81	.77	....	....	....	....	....
89...	D.W., Jan. 10 to 11, 1906...	.81	.75	....	....	....	....	....
	Average....................	0.79	0.75	0.74	0.74	0.73	0.75	0.74

The respiratory quotients for the 2-hour periods are given with the detailed statistics of the experiments. Unfortunately, but little reliance can be placed on these determinations for short periods save in those instances when the muscular activity of the subject was the same at the beginning and end of the experimental period. As has been pointed out previously, the exact determination of the average temperature of the large volume of air residual inside the chamber (4900 liters) is of the utmost importance to the accurate measurement of the oxygen consumption. Under like conditions of muscular activity at the beginning and end of each period, the average temperatures may readily be secured. Experience has shown that even minor differences between the muscular activity at the beginning and at the end of a period result in abnormal temperature observations for the residual air and consequently erroneous oxygen determinations and respiratory quotients. On the contrary, since the experimental day ends at 7 a. m. and the subject is quietly resting in bed, the respiratory quotients for 24 hours we believe to be as accurate as can be determined with the type of apparatus used in these experiments.

The marked acidosis accompanying certain fasting experiments and which we have reason to believe was not absent in some of those here reported, would have an effect upon the respiratory quotient. The conversion of partially oxidized fat into β oxybutyric acid, for example, would mean a taking up of oxygen unaccompanied by a corresponding liberation of carbon dioxide, and hence the oxygen consumption would be too large and the respiratory quotient too small. The exact effect of this acidosis on the quotient has not been computed since the respiratory quotients are not used in this discussion in their ordinary sense. The influence of such an absorption of oxygen unaccompanied

by a carbon dioxide liberation on the computation of the protein, fat, and carbohydrate by means of the method of simultaneous equations might be very complex. One serious objection to this method of computation is that the possibilities of intermediary metabolism are not considered in any way, since only the end products of metabolism are used for obtaining the data. It is believed, however, that acidosis did not proceed to any such degree in these experiments as to depreciate materially the accuracy of the computations of the protein, fat, and glycogen katabolized.

BODY MATERIALS KATABOLIZED.

The measurement of the end products of katabolism appearing in the respiratory gases and the urine furnishes the necessary data for determining the nature of the total katabolism. Aside from the interpretations of the nitrogen output and more specifically the recent emphasis laid upon the interpretation of the partition of the nitrogen in the urine, deductions from the respiratory quotient have been of greater value in indicating the nature of the total katabolism than have those from any other measured factor. But while the respiratory quotient is an admirable index of katabolism in short experiments in which the body is at absolute rest, provided that the body material has not previously been heavily drawn upon as a result of a protracted period of fasting, knowledge of the katabolic processes during inanition has been so deficient that the usual method of employing the respiratory exchange as an index of katabolism during a prolonged fast is hardly justified. In nearly all the studies of the respiratory exchange that have thus far been made, the so-called "nüchternwert" is of fundamental importance. It is necessary, however, in considering experiments of the nature of these here reported, to bear in mind that, even after 12 hours' fast, there may still be a considerable absorption from the intestine of food or at least of partially digested material. So long as this absorption is uniform, it introduces no material error into the determination of the fasting value, since its effect is measured along with the effect of the continued protein katabolism. The ingestion of even small amounts of food produces immediately very considerable changes in the respiratory exchange, and since in all experiments of short duration, the differential method is employed, it is important in studying factors influencing metabolism such as the ingestion of food and muscular work, that the respiratory exchange be measured prior to the ingestion of food or the beginning of muscular exercise. Hence, the value of the respiratory exchange, when the body is at absolute rest after a period of 12 hours without food, is usually taken as the basis for comparison. The differences, then, between the respiratory exchange during rest and that of the changed condition of the experiment indicate the effect of the change. The respiratory quotients obtained in the fasting experiments here reported, on the other hand, represent the resultant value of all the oxygen absorption and the total carbon dioxide production of each 24 hours.

As commonly used, the respiratory quotient excludes completely any consideration of the total nitrogen excretion, on the assumption that for the short period of the respiration experiment the katabolism of protein is constant. In the experiments made in this laboratory the protein broken down is as accurately and regularly measured as is the carbon dioxide production, and hence the total carbon dioxide excretion can be resolved into certain portions representing the katabolism of the various ingredients of the body.

The determination in metabolism experiments of the complete carbon dioxide and nitrogenous output alone has served heretofore as the basis for the computation of the proportions of protein and fat katabolized. In this computation it has been necessary to assume that the store of glycogen in the body remained constant during the experiment. Such an assumption may not be grossly erroneous during food experiments in which a maintenance ration is employed, though for periods of inanition where there may be very considerable drafts upon the store of glycogen, this method of computation, admittedly but approximate for experiments with food, may be entirely inadequate.

It was early recognized in this laboratory that a fundamental study of metabolism during inanition is necessary for a proper understanding of many physiological processes. But until the means were at hand for determining directly the oxygen consumption, it was apparent that such studies were of but little value. With the added data regarding the total amount of oxygen absorbed per day, a much more accurate apportionment of the total katabolism among protein, fat, and carbohydrate is possible. The apportionment is based upon the chemical determinations showing the losses of material to the body in terms of chemical elements, and for this reason especial care has been taken in making the elementary analyses. The losses to the body of nitrogen, carbon, hydrogen of organic matter, oxygen, water, and ash have all been determined as accurately as present methods of analysis will permit. The method of obtaining the gains and losses of chemical elements has been discussed in detail in connection with experiment No. 59 (see p. 36). From these gains or losses of elements it is possible by means of the method of simultaneous equations to compute the proportions of protein, fat, and carbohydrate katabolized. The detailed treatment of this subject is likewise given in connection with the discussion of the same experiment.

It is only necessary here, therefore, to compare the total amounts of protein, fat, and carbohydrate katabolized on different days of the different fasting experiments.

KATABOLISM OF PROTEIN.

Since the protein katabolized is computed from the nitrogen excretion by multiplying the amount of nitrogen by the factor 6.0, the discussion which has been accorded the total excretion of nitrogen during fasting applies in general in this connection. For while, as is well known, the nitrogen excreted

in the urine may have originated either in katabolized protein, purin bodies, creatine and creatinine, or preformed urea and other crystallized end products of katabolism, the only index of the total protein katabolism commonly used is the total excretion of nitrogen. Contrary to the natural supposition, the problem is most complicated in fasting experiments; for although under ordinary conditions with food the excretion of phosphorus and sulphur may be significant of the breaking down of protein, during inanition the excretions of nitrogen, sulphur, and phosphorus indicate profound disturbances in the katabolism.

A number of writers have attempted to compute the protein katabolized from the sulphur elimination, by assuming that the sulphur content of protein is relatively constant. The ratio of nitrogen to sulphur has been used in this connection. But the wide variations in the amounts of sulphur present in the various proteins existing in the body make it difficult to utilize with any degree of satisfaction the data obtained from the sulphur and nitrogen determinations and especially the ratio between them. Sherman[143] has computed the ratio of nitrogen to sulphur in a large number of vegetable and animal proteins. With the proteins of the body, the ratios range from 44.6 : 1 in oxy-hemoglobin to 5 : 1 in tendon mucin and osseo-mucoid; in myosin, serum globulin, and fibrinogen, the ratios are more constant, namely, 13.1 : 1, 14.3 : 1, and 13.3 : 1, respectively.

It is commonly assumed that body protein contains from 16 to 17 per cent of nitrogen, and since this percentage is not markedly different in the different animal proteins, the assumption is reasonably well grounded; but as has been shown above, the ratios of nitrogen to sulphur vary so widely as to practically preclude any scientific deductions from them regarding the nature and amount of the protein katabolized. The probability that there are at least two kinds of protein katabolism occurring in the body, namely, exogenous and endogenous, justifies the belief that there is a noticeable difference in the sulphur content of the two kinds of protein katabolized. While the nitrogen-sulphur ratio in fibrinogen, serum globulin, and myosin is fairly constant and this could properly be used if these were the only proteins katabolized, an examination of the ratios found in the experiments here reported (see table 209) shows that on only one day was the nitrogen-sulphur ratio as low as 14.12, namely, the fifth day of experiment No. 73. The ratios on all the other days were considerably higher, averaging not far from 16.8. This fact clearly indicates that material amounts of some form of protein with a lower sulphur content than that of myosin, serum globulin, or fibrinogen, must have been katabolized. Obviously, this ratio would be very much increased by an excretion of the sulphur-free extractives. The output of total creatinine, from the results obtained in these experiments (see table 203, p. 388) remains singularly con-

[143] U. S. Dept. Agr., Office of Expt. Sta. Bul. No. 121, p. 10.

stant throughout the fast, and according to the results of Brugsch (12), the purin bodies remain constant, at least on the last 8 days of a 30-day fast. This would imply that there was no excess in the excretion of extractive nitrogen. The sulphur determinations are of value in suggesting the nature rather than the total amount of the protein katabolized.

But little satisfaction attends the attempt to designate the kinds and amount of protein katabolized from the phosphorus output, for as has been shown in discussing the phosphorus excretion, the ratio of nitrogen to phosphorus is very much smaller than that occurring in the ordinary nucleo-proteins, which signifies that in all probability phosphatic material of the bones has been drawn upon and excreted.

An attempt has been made to measure protein katabolism by means of the chlorine excretion, assuming that the chlorine content of muscle is constant. From the discussion of the chlorine output during fasting, it is apparent that here again the results of the experiments are such as to preclude an accurate comparison between the elimination of chlorine and the amount of protein katabolized. Recent advances in the study of the significance of the partition of nitrogen would imply that a knowledge of the purin bodies, amino-acids, ammonia, and uric acid of the urine would furnish a much more accurate basis for the computation of the total protein katabolism than would perhaps the total nitrogen excretion. In the absence of more definite information regarding the nature of the nitrogenous material excreted during fasting, the only alternative is to follow the usual custom and to assume that the total nitrogen output indicates the total protein katabolism. In table 226 the amounts of protein katabolized per day, computed by multiplying the total nitrogen excretion by 6.0 are recorded. There are considerable differences in the body-weights of the subjects of these experiments, and consequently the amounts per kilo of body-weight are also recorded for purposes of comparison. Since there is a mass of evidence to show that muscular activity, at least when not excessive, does not influence the nitrogen output, the uniformity or lack of uniformity, between the total amounts of protein katabolized by different subjects and on different days by the same subject can be better compared than the katabolism of either carbohydrate or fat.

An examination of the figures in the table shows that during inanition, the protein katabolized on the first day of fasting varies from 35.0 grams to 79.5 grams. The average for the first day for the 14 experiments is 60.2 grams. Aside from the extremely low amount on the first day of experiment No. 71, the lowest result for the first day is 46.7 grams. On the basis of per kilo of body-weight, the fluctuations for the first day of the fast range from 0.61 to 1.44 grams, averaging 0.94 gram. The variations from the average protein katabolism per kilogram of body-weight indicate that there is no approach to uniformity in the results obtained on the first day without food.

The unusually low nitrogen output on the first day of experiment No. 71 has been the subject of much study. Unfortunately, since this was the first day of experimenting with this subject, no data are at hand regarding his protein katabolism prior to the fast nor, indeed, have we that accurate record of food consumed and nitrogen excreted during the several weeks before this fast that is available for the interpretation of the protein disintegration in one of the subsequent fasts.

TABLE 226.—*Protein katabolised in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.		Fourth day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59....	B. F. D., Dec. 18 to 20, 1903....	71.0	1.06	84.7	1.28	88.9	1.36	....	....
68 ...	A. L. L., Apr. 27 to 28, 1904....	73.6	1.02	78.2	1.11	....	....	....	....
69....	A. L. L., Dec. 16 to 19, 1904 ...	60.5	.82	85.6	1.18	90.2	1.25	77.8	1.09
71....	S. A. B., Jan. 7 to 10, 1905....	35.0	.61	66.2	1.17	78.6	1.39	64.4	1.16
73....	S. A. B., Jan. 28 to Feb. 1, 1905.	61.7	1.05	71.8	1.25	69.2	1.22	62.3	1.11
75....	S. A. B., Mar. 4 to 10, 1905....	73.4	1.23	74.7	1.26	78.1	1.34	69.8	1.21
77....	S. A. B., Apr. 8 to 11, 1905....	52.9	.86	64.7	1.07	65.9	1.12	68.7	1.19
79....	H. E. S., Oct. 13 to 14, 1905...	48.7	.86	86.1	1.55	....	....	....	....
80....	C. R. Y., Oct. 27 to 28, 1905....	46.7	.68	59.7	.90	....	....	....	....
81....	A. H. M., Nov. 21 to 22, 1905....	54.7	.89	78.3	1.30	....	....	....	....
82....	H. C. K., Nov. 24 to 25, 1905....	56.3	.79	86.2	1.23	....	....	....	....
83....	H. R. D., Dec. 5 to 6, 1905....	79.5	1.44	81.2	1.49	....	....	....	....
85....	N. M. P., Dec. 9 to 10, 1905....	68.2	1.02	68.1	1.04	....	....	....	....
89....	D. W., Jan. 10 to 11, 1906....	59.9	.77	86.8	1.13	....	....	....	....
	Average..................	60.2	.94	76.6	1.21	78.5	1.28	68.6	1.15

Experiment number.	Subject and duration of experiment.	Fifth day.		Sixth day.		Seventh day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
73....	S. A. B., Jan. 28 to Feb. 1, 1905............	59.9	1.08	....	....	....	....
75....	S. A. B., Mar. 4 to 10, 1905................	65.2	1.15	64.4	1.14	60.8	1.08
	Average............................	62.6	1.11	64.4	1.14	60.8	1.08

The amounts of protein katabolized in the different experiments are much more nearly uniform on the second day of fasting, the minimum being 59.7 grams and the maximum 86.8 grams. The average for the 14 experiments is

76.6 grams, a material increase over the average for the first day, thus substantiating the contention made by Prausnitz[143] that the protein katabolism on the first day of fasting is regulated in large measure by the amount of glycogen in the body. Furthermore, reference to the quantities of glycogen katabolized (see table 228) on the second days of these experiments shows that the amounts of katabolized glycogen in all but one instance were greatest on the first day.

Computed on the basis of per kilogram of body-weight, the protein katabolism on the second day of fasting is reasonably constant, experiments Nos. 79 and 80 being the marked exceptions. Omitting these experiments, the widest variation from the average (1.21 grams) is 0.28 gram.

The uniformity of the protein katabolism is still further supported by the results on the third day of fasting, the maximum amount being 90.2 grams, the minimum 65.9 grams, and the average 78.5 grams, somewhat more than the average for the second day. The average per kilogram of body-weight is 1.28 grams, and the fluctuations from this average in the different experiments are very small.

Similarly, constancy in the results from day to day is observed on the fourth day of fasting, the amounts on the basis of per kilogram of body-weight being practically uniform after the third day.

In comparing the results of protein katabolism as indicated in this table, it is important to bear in mind that the factor for the computation of protein here employed is 6.0, while the factors 6.3 and 6.25 are commonly used to express the ratio between nitrogen and protein. Obviously, the use of either of these latter figures, would indicate a somewhat greater protein katabolism than is recorded in the table.

The results show that on the first day of fasting the amounts are extremely irregular and that the fasting protein katabolism can not be said to be established before the second day.

The bearing of the protein katabolism on the protein requirement, the influence of the previous store of glycogen,[144] fat and protein, and the relation of the protein katabolism to the total active mass of protoplasmic tissue are problems all closely related, but discussion of them in this place would be beyond the confines of this report. With the publication of experiments made subsequent to these here reported, it is hoped that these problems may be more fully dealt with.

Certain of the data accumulated in this series of experiments, while admittedly too meager to serve as the basis for the enunciation of a theory of the effect of inanition upon protein katabolism, are sufficiently suggestive to warrant more complete examination.

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[143] Zeit. f. Biologie (1892), 29, p. 151.

[144] The interesting discussion of the relation between the store of glycogen in the body and the proteid katabolism by Landergren (Skan. Archiv f. Physiol. (1903), 14, p. 169), is supplemented by the observations on the actual glycogen katabolism observed in these experiments.

In the discussion of the creatinine output (see p. 389) the interpretation of the results obtained in these experiments viewed in the light of the Folin theory of protein metabolism was pointed out. The attempts to harmonize the results of the fasting experiments with this theory showed that, while the body during fasting may protect reserve tissue protein to a greater extent than during ordinary conditions of nutrition, there is also the possibility that fasting may result in a greater encroachment upon stored organized body material. The fact that the total creatinine output remained constant even during a 7-day fast was taken as an indication that no greater drafts were made upon organized protein than during complete nutrition.

The presence of preformed creatine in the urine of fasting man was considered the result of a decrease in the power of the body to dehydrate the creatine resulting from protein katabolism. In support of this view is the remarkable fact that the total creatinine elimination, i. e., preformed creatinine plus preformed creatine (expressed in terms of creatinine), remains constant throughout the fast. Without losing sight of the possibility of this explanation, it is of interest to consider another possible correlation of these data.

The exact nature of the endogenous protein katabolism is not known. That it is essentially different from the exogenous is by no means inconceivable, and if the assumption is made that tissue protoplasm is broken down, the marked decrease in the total protein katabolism during prolonged fasting would imply that the katabolism of tissue protein would likewise decrease. The total creatinine output considered in the light of the foregoing discussion then would indicate that the tissue katabolism was supplemented by some other source of creatinine.

As a matter of fact the preformed creatinine elimination decreases as the fast progresses and the preformed creatine increases. The presence of considerable amounts of creatine in flesh would suggest that in the katabolism of body flesh during inanition this creatine was liberated and that it was excreted by the body as such. This involves no assumption regarding the source of the preformed creatinine excreted during inanition. This latter may be derived from the katabolism of protein or it may be taken from the preformed creatine in the muscle, dehydrated to creatinine and so excreted, but, unfortunately, no evidence is at hand to show clearly this phase of intermediary metabolism.

The suggestion above, therefore, assumes that the so-called endogenous protein katabolism during inanition decreases as the fast progresses, using the preformed creatinine excretion as the measure of endogenous katabolism. The excretion of preformed creatine indicates the katabolism of flesh.

According to the results of Van Hoogenhuyze and Verploegh (**11**), each kilogram of flesh contains not far from 4.2 grams of creatine.[144a] In the later

[144a] Grindley: Jour. of Biol. Chem. (1907), 2, p. 4, has recently found 4.1 grams of creatine in one kilogram of lean beef.

days of fasting in the Middletown experiments the total amount of protein katabolized was not far from 60 grams, corresponding to about 300 grams of flesh. Assuming the whole protein katabolism to have resulted from katabolized flesh about 1.2 grams of creatine would have been set free.

The amounts actually found are much less than this theoretical quantity. The absence of uniformity in the nitrogen-sulphur ratio points strongly to a protein katabolism other than that of muscle. As the fast progresses this ratio gradually approaches that of muscle protein. It is suggested, then, that the true measure of flesh or muscle katabolized may in fasting man be the amount of preformed creatine excreted in the urine. According to this hypothesis the total protein katabolism on the first few days of fasting involves little muscle protein, but as the fast progresses the muscle protein becomes disintegrated and releases creatine which is excreted unchanged. The muscle katabolism does not comprise the total protein katabolism, for the creatine excretion is practically constant on the fifth, sixth, and seventh days. The nitrogen-sulphur ratio likewise becomes constant during these periods, and the total amount of creatine excreted would correspond to that in but 125 grams of katabolized flesh. There must be a continuous protein katabolism other than that of flesh, which has reached a minimum on the fifth day. This suggestion of the use of preformed creatine eliminated in the urine as an index of flesh katabolized has at least the value of indicating many possible research problems. Our experimental data are far too limited to bring the discussion out of the field of speculation.

Folin [148] has shown that, contrary to the prevailing opinion, creatine ingested, especially after a period with food in which the protein content of the body has been somewhat lowered, i. e., after a low protein diet, is not excreted unchanged, nor indeed is it excreted in the form of creatinine. There is, moreover, no corresponding increase in the total nitrogen elimination, and hence it would appear that under these conditions the creatine is retained by the body. On the other hand, his experiments show that when the body is surcharged with protein, as after a high protein diet, the creatine ingested is in large part excreted as such. These results are difficult to harmonize with those obtained in the fasting experiments here reported unless some such assumption as is suggested above is made.

During a low protein diet the creatine of the muscles is apparently drawn upon and whether it is excreted as creatine or as creatinine we as yet do not know. Under such conditions, then, the ingestion of creatine supplies the drafts upon the body creatine and there is no loss through the urine. It would be interesting to see how soon the store of creatine in the body would be replenished and the excess excreted in the urine with the subject remaining on a low protein diet.

[148] Festschrift für Olof Hammarsten (1906).

The excretion of neutral sulphur parallels in a marked manner that of preformed creatinine. While Folin is inclined, according to recent statements,[146] to regard the excretion of neutral sulphur in a somewhat different light than when he enunciated his theory of protein metabolism, it is significant that, in fasting experiments, the excretion of preformed creatinine and neutral sulphur should decrease as the fast progresses at practically the same rate. But one explanation for this phenomenon appears at present. Possibly during the earlier stages of fasting, the fluid proteins are first drawn upon. This represents a condition of katabolism not unlike that during the ordinary digestion of food. It may be measured by the total creatinine and the neutral sulphur output. The body becomes depleted of its fluid protein as the fast continues, and then the muscle is disintegrated and the creatine in the flesh katabolized is set free. Under ordinary conditions the body may cleave the protein molecule to creatinine during the process of katabolism, but be unable to dehydrate preformed creatine to creatinine. On this assumption it would appear that the preformed creatine existing in the muscles does not undergo any katabolism, that it is a relatively constant quantity and only when actual muscle substance is drawn upon, as during inanition, is it excreted as such.

The remarkable constancy of the total creatinine excretion as the fast progresses does not justify final conclusions regarding the excretion of creatine in flesh katabolized during the later days of fasting. It would seem more than a coincidence that the amount of creatinine resulting from endogenous protein katabolism plus the amount of creatine in flesh katabolized should remain constant during the whole of the 7-day fast.

Recently Lichtenfelt,[147] observing the influence of inanition upon the composition of fish muscle, found that the muscle became richer in water when due allowance was made for the loss of fat and protein.

This observation, likewise, is of interest in connection with the older assumption that when flesh was katabolized the water in it was liberated and excreted. According to Lichtenfelt the water is not necessarily eliminated, but the muscle has a higher water content.

While Lichtenfelt's results indicate that there may be a loss of protein from muscle, Abderhalden, Bergell & Dörpinghaus[148] found on investigating the proteids of the blood and the body, by the esterfication method, that there was no difference to be observed when comparing the determinations on animals in health and animals after inanition, thus showing that the residual protein had not been altered as a result of inanition.

While undoubtedly a portion of the katabolized protein is that of muscle, a significant fraction is in all probability derived from some of the larger organs.

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[146] Extract from a personal letter cited by Shaffer, Amer. Journ. of Physiol. (1906), 16, p. 274.
[147] Archiv f. d. ges. Physiol. (1904), 103, p. 402.
[148] Zeit. f. physiol. Chem. (1904), 41, p. 153.

It appears clearly established that there is a marked diminution in the size of the liver[149] and pancreas as well as other glandular organs, and in all probability these organs are drawn upon to a considerable extent to furnish the protein for katabolism. Since they rapidly regain their original size on the ingestion of food, it is probable that the fluid of the cell rather than the organized cell proteid is the portion drawn upon.

KATABOLISM OF FAT.

It has been customary in all experiments in which the katabolism of fasting man has been measured, to assume that the total fasting metabolism was sustained by the katabolism of protein and fat. The amounts of these compounds katabolized by a man at rest were computed from analyses of the respiratory products and the urinary nitrogen. The total protein katabolism was computed from the nitrogen excreted in the urine and the amount of carbon in the protein was calculated from the weight of protein katabolized. The carbon from protein was deducted from that of the carbon dioxide and the carbon in the urine, and the remainder was considered to have resulted from the katabolism of fat. This procedure has been common in the calculation of all metabolism experiments up to the publication of the direct determination of oxygen in some of the Middletown experiments.[150] With the direct determination of oxygen, the data are available for computing by means of simultaneous equations (see p. 38) the quantities of protein, fat, and carbohydrate katabolized. The amounts of fat katabolized per day and per kilogram of body-weight in fasting experiments have been computed and are recorded in table 227.

In all cases there was a material draft upon body fat which was never less than 106.6 grams per day. On one day 203.6 grams were katabolized. The amounts for the first day of fasting ranged from 106.6 to 156.2 grams, and averaged 135.1 grams. The katabolism per kilogram of body-weight averaged 2.10 grams.

In all but one instance, more fat was katabolized on the second day of the fast, the average amount for the 14 experiments being 165.9 grams or 2.61 grams per kilogram of body-weight. The amounts for the third day were by no means as regular as might be expected, the quantities ranging from 183.4 grams in experiment No. 59 to 137.7 grams in experiment No. 77. On the basis of per kilogram of body-weight, the range was from 2.80 to 2.25 grams. The average fat katabolism of the 6 experiments was 155.2 grams, somewhat less than the average for the second day of all the experiments. The average amount on the fourth and fifth days was about 147 grams, and on the sixth and seventh days about 15 grams less per day. The largest averages, per kilogram of body-weight, are found on the second and fifth days, while on the first and sixth days, the smallest amounts appear. The minimum katabolism per kilo

[149] Possibly due to depletion of the store of glycogen.
[150] U. S. Dept. Agr., Office of Expt. Sta. Bul. 175 (1907).

of body-weight was observed on the first day of the fast. A proper interpretation of these fluctuations in the katabolism of fat can not be made without a comparison of the amounts of glycogen which were simultaneously katabolized.

The large amount of fat drawn upon by the body to support its vital functions is of special interest in connection with the question of acidosis during fasts. This observation is wholly in accord with the modern conceptions regarding the formation of organic acids from fat.

TABLE 227.—*Fat katabolized in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.		Fourth day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59....	B. F. D., Dec. 18 to 20, 1903....	150.7	2.25	156.6	2.37	183.4	2.80	....	....
68....	A. L. L., Apr. 27 to 28, 1904....	145.1	2.01	160.6	2.27	....	....	....	....
69....	A. L. L., Dec. 16 to 19, 1904....	184.9	1.84	174.3	2.40	161.7	2.25	169.2	2.37
71....	S. A. B., Jan. 7 to 10, 1905....	116.5	2.02	152.3	2.68	142.9	2.53	133.0	2.39
73....	S. A. B., Jan. 28 to Feb. 1, 1905.	106.6	1.82	151.7	2.63	152.6	2.68	139.2	2.48
75....	S. A. B., Mar. 4 to 10, 1905....	126.4	2.12	147 5	2.49	153.0	2.62	144.7	2.51
77....	S. A. B., Apr. 8 to 11, 1905....	135.0	2.20	171.9	2.85	137.7	2.34	149.9	2.60
79....	H. E. S., Oct. 13 to 14, 1905....	132.6	2.34	158.2	2.85	....	....	....	....
80....	C. R. Y., Oct. 27 to 28, 1905....	141.6	2.07	190.1	2.85	....	....	....	....
81....	A. H. M., Nov. 21 to 22, 1905 ..	146.9	2.39	161.2	2.67	....	...	....	....
82....	H. C. K., Nov. 24 to 25, 1905....	140.1	1.97	203.6	2.90	....	..	....	...
83....	H. R. D., Dec. 5 to 6, 1905....	156.2	2.52	143.9	2.63	....	....	...	....
85....	N. M. P., Dec. 9 to 10, 1905....	127.4	1.91	168.0	2.56	....	....	....	....
89....	D. W., Jan. 10 to 11, 1906....	131.8	1.68	182.6	2.37	....	...	....	...
	Average..................	135.1	2.10	165.9	2.61	155.2	2.54	147.2	2.47

Experiment number.	Subject and duration of experiment.	Fifth day.		Sixth day.		Seventh day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
73....	S.A.B., Jan. 28 to Feb. 1, 1905............	148.1	2.68	....	....	....	....
75....	S.A.B., Mar. 4 to 10, 1905...............	144.7	2.54	129.8	2.30	132.5	2.36
	Average	146.4	2.61	129.8	2.30	132.5	2.36

There is good reason to suppose that the slight muscular activity exhibited by the subjects of these experiments could not have had any marked influence on the protein katabolism. Even slight variations in muscular activity, however, have considerable effect upon the amount of fat katabolized, hence it is

necessary to consider the fat katabolism along with the variations in muscular activity in order to obtain an intelligent conception of the causes for the variations in the results for fat. In a subsequent section the relation between the muscular activity and protein, fat, and carbohydrate katabolism, along with a number of other factors of metabolic activity, is considered.

KATABOLISM OF GLYCOGEN.

In all respiration experiments thus far made, in which the total income and outgo for 24 hours has been determined, it has been assumed that the store of glycogen in the body remains constant during the experiment, or if there are fluctuations during the day, that the amount in the body at the beginning and end of each experimental day remains unchanged. For experiments with normal diets in which a maintenance ration is supplied, this assumption may not be entirely erroneous. The study of fasting katabolism, on the other hand, involves such abnormal conditions that the assumption that the glycogen content of the body remains constant is hardly justified. With the development of the present form of apparatus in use in the laboratory of Wesleyan University, it was possible to obtain direct evidence regarding the absolute amount of oxygen absorbed by man per day. It has recently become possible to compute the loss of body material, not only the amounts of protein and fat, but also the amount of glycogen, and in these experiments the quantities of glycogen katabolized per day, have been computed. All earlier experimenters assumed that the total carbon elimination minus the carbon of the katabolized protein, was derived from the katabolism of fat, but accurate measurements of the oxygen intake permit an apportionment between the fat and the glycogen of the carbon eliminated other than carbon of katabolized protein.

Food was administered in the first series of experiments with which this apportionment was attempted,[181] although in some instances in amounts considerably less than that required for maintenance. The first observations regarding the glycogen katabolism of fasting man made with this apparatus are here recorded. The method of computing the amount of glycogen has been elaborated in connection with experiment No. 59, and the possible errors of the method (and they certainly exist) have been pointed out in a discussion elsewhere.[182]

Recognizing, then, the possibilities of error in this determination, the results are given as representing the closest approximation to the true glycogen katabolism that, so far as we are aware, has yet been made. The respiratory quotient commonly used for determining the apportionment of the combustion between fat and glycogen is not, at least in its ordinary sense, here used.

[181] U. S. Dept. Agr., Office of Expt. Sta. Bul. 175.
[182] Carnegie Institution of Washington Publication No. 42; U. S. Dept. Agr., Office of Expt. Sta. Bul. 175.

The computations are based on the loss to the body of nitrogen, carbon, hydrogen, and oxygen, the elementary analyses furnishing the data whereby these losses are determined.

The amounts of glycogen katabolized per day together with the quantities per kilogram of body-weight are recorded in table 228.

TABLE 228.—*Glycogen katabolized in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.		Fourth day.	
		Total.	Per kilogram of body-wt.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-wt.	Total.	Per kilogram of body-wt.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
59..	B. F. D., Dec. 18–20, 1903...	89.2	1.33	59.4	0.90	4.2	0.06	....	....
68..	A. L. L., Apr. 27–28, 1904...	112.5	1.56	72.6	1.03	....	....	....	....
69..	A. L. L., Dec. 16–19, 1904...	103.8	1.41	31.5	.43	32.7	.46	15.3	0.21
71..	S. A. B., Jan. 7–10, 1905....	181.6	3.15	29.7	.52	22.0	.39	25.3	.46
73..	S. A. B., Jan. 28–Feb. 1, 1905	135.3	2.31	18.1	.31	7.4	.13	21.6	.39
75..	S. A. B., Mar. 4–10, 1905....	64.9	1.09	23.1	.39	5.4	.09	25.2	.44
77..	S. A. B., Apr. 8–11, 1905....	92.7	1.51	14.9	.25	58.9	1.00	29.2	.51
79..	H. E. S., Oct. 13–14, 1905...	117.6	2.08	40.0	.72	....	....	....	....
80..	C. R. Y., Oct. 27–28, 1905...	103.6	1.51	17.1	.26	....	....	....	....
81..	A. H. M., Nov. 21–22, 1905..	28.7	.47	[1]25.7	[1] .43	....	....	....	....
82..	H. C. K., Nov. 24–25, 1905..	165.6	2.33	44.7	.64	....	....	....	....
83..	H. R. D., Dec. 5–6, 1905....	32.8	.59	41.6	.76	....	....	....	....
85..	N. M. P., Dec. 9–10, 1905....	146.0	2.18	91.6	1.40	....	....	....	....
89..	D. W., Jan. 10–11, 1906.....	165.6	2.12	39.6	.51	....	....	....	....
	Average..............	110.0	1.69	[2]40.3	[2]0.62	21.8	0.36	23.3	0.40

Experiment number.	Subject and duration of experiment.	Fifth day.		Sixth day.		Seventh day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
73...	S. A. B., Jan. 28–Feb. 1, 1905.......	[1]10.8	[1]0.20	....	....	....	....
75...	S. A. B., Mar. 4–10, 1905...........	8.2	.14	21.7	0.38	18.7	0.33
	Average.....................	[2] 8.2	[2]0.14	21.7	0.38	18.7	0.33

[1] Glycogen gained.
[2] Omitting glycogen gained.

The figures above show in a striking manner the great possibilities of error involved in the assumption made in all earlier fasting experiments with men, that the store of glycogen in the body is not materially drawn upon during the earlier days of fasting. On the first day of fast the amounts katabolized varied in these 14 experiments from 28.7 grams to 181.6 grams, and on the

average for 14 experiments there were 110 grams of glycogen katabolized on the first day. The quantities per kilogram of body-weight on the first day show marked differences since the variations in body-weight of the different subjects were by no means as great as the fluctuations in the actual amount of glycogen katabolized. On the second day of fasting, which, as has been seen in the previous discussion, appears to represent more nearly than the first day, the true fasting metabolism, the quantity of glycogen is considerably less, ranging from 14.9 to 91.6 grams. It is to be noted that in one of these experiments, No. 81, the records indicate a gain of glycogen amounting to 25.7 grams. Similarly a gain is recorded on the fifth day of experiment No. 73. Deferring for the moment the discussion of these gains of glycogen, it is seen that the amount of glycogen katabolized in the average of 13 experiments on the second day was 40.3 grams. On the basis of per kilogram of body-weight 0.62 gram was katabolized. The large amounts on the first day of fasting are thus very materially reduced on the second day. Unfortunately, but few experiments continued after the second day, the average amount of glycogen for the third day of 6 experiments being 21.8 grams. Wide fluctutions appear, however, even on this day, ranging from 4.2 to 58.9 grams. On the fourth day the glycogen katabolized was nearly constant in the 5 experiments, averaging 23.3 grams. The quantities katabolized on the fifth, sixth, and seventh days are somewhat lower, the amounts showing a general tendency to decrease as the fast progresses. The lowest result is noted on the third day of the longest experiment, while on the fourth, sixth, and seventh days, the total amounts katabolized are nearly equal to those of the second.

Marked irregularities are to be noted in the katabolism as the fast progresses in practically all the experiments.

Storage of glycogen.—On 2 of the 43 fasting days here reported, the figures indicate a storage of glycogen. It was hoped that the data would perhaps indicate the exact source of the stored glycogen, but, unfortunately, the instances of such storage are too few and the quantities stored too small to justify definite conclusions from the results as recorded, and, accordingly, these experiments fail to throw important light on the much discussed question regarding the source of glycogen.

It may be questioned whether the analytical methods and the computations used in these experiments are sufficiently accurate to warrant the belief that there is an actual storage of glycogen in these two instances. But a close examination of the figures will show that the oxygen consumption and carbon dioxide output may well include a cleavage of protein or oxidation of fat to form glycogen.[186] It is much to be regretted that definite experiments to study this problem with this apparatus have not as yet been reported, although at the

[186] See discussion of probable error in oxygen determination on one of these days, p. 514.

moment of writing experiments are in progress which will, it is hoped, contribute to the discussion of this matter.

Total glycogen content of the body.—The assumption has commonly been made that the total glycogen content of the body is not far from 400 grams. By means of phloridzin, the glycogen of the body of a dog has been rapidly driven out in the urine, and the data thus obtained furnish information regarding the glycogen content of the animal under experimentation. With man the estimations are necessarily founded on a much less scientific basis.

The data here presented give some evidence regarding the quantities of glycogen in the body since the total amounts katabolized during varying periods of inanition have been computed. The greatest amount katabolized during the first 24 hours without food was, as has previously been stated, 181.6 grams. The greatest output measured during a 2-day fast is that of experiment No. 85, namely, 238 grams. The largest amount recorded at the end of 3 days of fasting is that in experiment No. 71, 233 grams, a little less than that of the 2 days of experiment No. 85. For 4 days the largest recorded amount (259 grams) is in experiment No. 71. This amount is, as a matter of fact, not even exceeded by the total glycogen katabolized in the 7 days of experiment No. 75. Since it is highly probable that only a moderate portion of the total glycogen of the body is oxidized in a fasting man during a period of inanition no longer than 4 days, it would appear that the estimate of 400 grams of glycogen for the content of the body is, if anything, too small rather than too large.

WATER.

The factors involved in a complete study of the income and outgo of water during inanition are the drinking-water and the water of urine, respiration and perspiration, and feces.[184]

In striking a water balance, the income, namely, water of drink, is deducted from the outgo, i. e., water of respiration and perspiration, urine and feces. There is one factor affecting this balance, however, which must be taken into consideration, namely, the portion of the water of outgo which is not preformed water but represents the water of oxidation of the amounts of protein, fat, and glycogen katabolized. As the result of the chemical transformations in the body, there is an actual formation of water from the oxidation of organic hydrogen of body material katabolized, and hence the output of water may be said to consist of two fractions: first, preformed water, i. e., that taken in the drink or abstracted from the body tissues and fluids; and second, the water of oxidation of organic hydrogen. In experiments of the nature of these here reported, where a complete balance of intake and outgo is attempted, the data are available for computing not only the loss from the body of preformed water, but also the amount of water resulting from the oxidation of organic hydrogen.

[184] Special treatment has been accorded the feces in the fasting experiments and therefore the water of feces is not discussed here. See p. 120.

The wide variations in the amounts of drinking-water consumed by the different subjects of these experiments have been discussed in detail in an earlier section (see p. 348). The actual amounts consumed per 24 hours have also been recorded in table 193. Similarly, the output of water of respiration and perspiration has received special discussion in a preceding section, as has also the amount of water in the urine. It remains, therefore, to consider in detail the amount of water of oxidation of organic hydrogen and the loss of preformed water.

Water of oxidation of organic hydrogen.—The water resulting from the oxidation of organic hydrogen may be directly computed from the data for the quantities of protein, fat, and glycogen katabolized and the analysis of the urine. The percentages of hydrogen in these compounds are known (see p. 37), and the total quantity of organic hydrogen contained in them may be computed. By deducting the organic hydrogen in the solid matter of the urine, the total hydrogen oxidized is obtained. From these data in the different experiments, the results for the water of oxidation of organic hydrogen as recorded in table 229 may be obtained. The computation actually used in obtaining these results was slightly different in form. In the calculations of the quantities of protein, fat, carbohydrate, and water katabolized, according to the method of simultaneous equations (see p. 38), the values found for water represent only the preformed water involved in the katabolism, for the organic hydrogen of the protein, fat, and glycogen had already been apportioned among the various quantities of these three compounds. Deducting the preformed water, as computed by the formulæ, from the total water output, gives the values for the water of oxidation of organic hydrogen.

The water of oxidation of organic hydrogen is dependent upon the amounts of protein, fat, and glycogen katabolized, and in nearly every case the amounts decrease as the fast progresses. The largest amount in the fasting experiments occurred on the second day of experiment No. 82, and the smallest amount on the seventh day of experiment No. 75. The average water of oxidation for all the fasting experiments is 209 grams, corresponding to the oxidation of 23.4 grams of organic hydrogen. The factors affecting the amounts of protein, fat, and glycogen katabolized, therefore, obviously affect the amounts of organic hydrogen oxidized.

Each gram of organic hydrogen oxidized in food or body material is accompanied by a total liberation of about 70 calories of energy.[185] The comparison of the organic hydrogen oxidized in these experiments with the total heat output is deferred to the discussion of the heat elimination.

Loss of preformed water.—While the water of oxidation of organic hydrogen is directly proportional to the amounts of hydrogen in the protein, fat, and glycogen katabolized, and is, therefore, not properly to be considered in a water

[185] See the computations made by Magnus-Levy. Physiologie des Stoffwechsels (1905), p. 424. Thus during fasting 32 grams of hydrogen corresponds to a total heat output of not far from 2300 calories.

balance, an entirely distinct set of factors determines the loss of preformed water. The computation of the output of preformed (katabolized) water has already been discussed. Deducting from this the water of drink, the loss of preformed water is obtained. The amounts of this loss from the body during inanition are given in table 229.

In one instance there is an actual gain of preformed water to the body noted, namely, on the first day of experiment No. 75. The most striking feature of these results is the very large amount of water lost during inanition. It is to be remembered that all these subjects were supplied with drinking-water, and hence it is fair to assume that the needs of the body, so far as thirst would dictate, could be fully met. It is furthermore to be noted that in some instances, the subjects actually drank enormous volumes of water, so it is probable that the body was liberally supplied, and yet in a majority of instances the subjects continually lost preformed water from the body.

The source of this loss is difficult to determine. It has generally been considered that the katabolism of protein results in the breaking down of flesh which contains a considerable amount of water. Assuming that each gram of protein is combined with water to form 4.9 grams of flesh, the total amount of water resulting from the katabolism of the flesh on each day of the experiments may be determined by multiplying the weight of protein by the factor 3.9. The amounts of water thus computed are recorded in column *a* of the table. If it be assumed that in the katabolism of the various amounts of flesh, the water was liberated and excreted, it is seen that in a majority of experiments the water from the katabolism of flesh is but a small part of the total loss of preformed water. Especially is this true in a number of the shorter experiments. The figures show, however, no relation whatever between the quantity of protein and flesh katabolized and the loss of preformed water, and we are forced to the conclusion that if the water of the flesh is excreted as preformed water, it forms but a small portion of the total, especially in the first days of inanition. Thus it would appear that, at least in short experiments during inanition, there was a gross error involved in the calculations of the loss of water frequently made on the basis of flesh katabolized. It is clear, therefore, that in the earlier days of fasting, the body may lose very much larger amounts of water than are represented by the water of flesh katabolized.

A comparison of the amounts of fat and carbohydrate katabolized with the loss of preformed water on the different days is likewise inconclusive.

It is conceivable that the glycogen in the liver and muscles holds a certain amount of water as water of hydration,[186] but there is as yet no evidence to warrant this assumption. In certain of the experiments it may appear that the large amounts of glycogen katabolized were coincident with the large losses of preformed water, but there are a number of marked exceptions to this parallelism and no definite deduction can be drawn.

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[186] See Magnus-Levy, loc. cit.

TABLE 229.—*Distribution of water in metabolism experiments with and without food.*

Experiment number.	Subject and date.	(a) Water in flesh (protein ×3.9).	(b) Loss of preformed water.	(c) Loss of preformed water greater + or less − than water in flesh (b—a).	(d) Water of oxidation of organic hydrogen.
	Experiments without food.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
59......	B.F.D.: Dec. 18–19, 1903.....	277	905	+ 628	229
	Dec. 19–20, 1903.....	330	296	− 34	223
	Dec. 20–21, 1903.....	347	404	+ 57	222
68......	A.L.L.: Apr. 27–28, 1904.....	287	1192	+ 905	241
	Apr. 28–29, 1904.....	305	703	+ 398	237
69......	A.L.L.: Dec. 16–17, 1904.....	236	286	+ 50	221
	Dec. 17–18, 1904.....	334	659	+ 325	231
	Dec. 18–19, 1904.....	352	203	− 149	221
	Dec. 19–20, 1904.....	304	386	+ 82	213
71......	S.A.B.: Jan. 7– 8, 1905.....	137	440	+ 303	235
	Jan. 8– 9, 1905.....	258	476	+ 218	200
	Jan. 9–10, 1905	307	564	+ 257	191
	Jan. 10–11, 1905.....	251	306	+ 55	176
73......	S.A.B.: Jan. 28–29, 1905.....	241	618	+ 377	210
	Jan. 29–30, 1905.....	280	621	+ 341	196
	Jan. 30–31, 1905.....	270	349	+ 79	188
	Jan. 31–Feb. 1, 1905..	243	362	+ 119	180
	Feb. 1– 2, 1905.....	234	300	+ 66	170
75.....	S.A.B.: Mar. 4– 5, 1905.....	286	− 48	− 334	195
	Mar. 5– 6, 1905.....	291	564	+ 273	189
	Mar. 6– 7, 1905.....	305	529	+ 224	187
	Mar. 7– 8, 1905.....	272	453	+ 181	185
	Mar. 8– 9, 1905....	254	216	− 38	173
	Mar. 9–10, 1905.....	251	255	+ 4	166
	Mar. 10–11, 1905.....	237	239	+ 2	164
77......	S.A.B.: Apr. 8– 9, 1905.....	206	942	+ 736	208
	Apr. 9–10, 1905.....	252	965	+ 713	202
	Apr. 10–11, 1905.....	257	927	+ 670	192
	Apr. 11–12, 1905.....	268	578	+ 310	188
79......	H.E.S.: Oct. 13–14, 1905.....	190	661	+ 471	220
	Oct. 14–15, 1905.....	336	959	+ 623	215
80......	C.R.Y.: Oct. 27–28, 1905.....	182	1682	+1500	217
	Oct. 28–29, 1905.....	233	1365	+1132	224
81......	A.H.M.: Nov. 21–22, 1905.....	213	753	+ 540	186
	Nov. 22–23, 1905.....	305	1082	+ 777	179
82......	H.C.K.: Nov. 24–25, 1905.....	220	267	+ 47	256
	Nov. 25–26, 1905.....	336	1327	+ 991	261
83......	H.R.D.: Dec. 5– 6, 1905.....	310	168	− 142	209
	Dec. 6– 7, 1905.....	317	603	+ 286	197
85......	N.M.P.: Dec. 9–10, 1905.....	266	1010	+ 744	240
	Dec. 10–11, 1905.....	266	497	+ 231	252
89......	D.W.: Jan. 10–11, 1906.....	234	1056	+ 822	248
	Jan. 11–12, 1906.....	338	694	+ 356	244
	Experiments with food.				
70......	A.L.L.: Dec. 20–21, 1904.....	305	160	− 145	226
	Dec. 21–22, 1904....	230	204	− 26	244
	Dec. 22–23, 1904.....	238	−150	− 388	275
72.....	S.A.B.: Jan. 11–12, 1905.....	249	38	− 211	184
74......	S.A.B.: Feb. 2– 3, 1905.....	251	− 52	− 303	184
	Feb. 3– 4, 1905.....	193	−106	− 299	185
	Feb. 4– 5, 1905.....	159	−127	− 286	187
76......	S.A.B.: Mar. 11–12, 1905.....	238	179	− 59	191
	Mar. 12–13, 1905.....	167	−285	− 452	194
	Mar. 13–14, 1905.....	183	10	− 173	206

Knowing that the fat in the body does not hold material amounts of water, it is hardly conceivable that the excretion of preformed water should have any relation to the fat katabolized and an inspection of the figures here given shows that no such relation can be observed.

With the enormous amounts of drinking-water consumed by some of these subjects, it may appear that the loss of preformed water was in a measure influenced by the quantities of drinking-water consumed. Here again comparisons fail to show any clear relationship. For example, it might be expected that with large amounts of drinking-water, the body would be supercharged with it and thus a minimum loss of preformed water occur, and yet in some of the experiments, where the largest loss occurred, the subjects consumed very liberal amounts of drinking-water.

Although no relation can be clearly seen between the quantities of protein, fat, and glycogen katabolized and the loss of preformed water, there is one factor which has previously been treated in this report, which apparently has some relation to this loss. That factor is the ratio between the amount of water in urine and the water in drink, discussed on page 348. This ratio has been given in column *e* of table 193. Comparing the ratios in this column with the losses of preformed water, it is noted that when there is a high ratio, there is a large loss of preformed water. This is to be expected since the quantities of water of respiration and perspiration remain relatively constant throughout the fasts.

An examination of the figures for the longer fasting experiments shows that, in general, the loss of preformed water becomes less and less as the fast progresses, and from a comparison of the amounts of water lost with the water of flesh katabolized in the case of experiment No. 75, it might appear that during the earlier days of fasting, there is a very considerable loss of preformed water to the body other than that of the protein katabolized, and that as the fast progresses this extra loss of water diminishes until, on the sixth and seventh days of fasting, the water of flesh katabolized corresponds to the preformed water lost. Apparently, at the beginning of the fast there is no connection whatever between the preformed water lost and the other factors of katabolism. It seems, therefore, that the body must have a large residuum of water other than that in muscle and glands. In the muscles, the ratio of the organic matter to the water is presumed to be very fixed. Indeed, until recently[187] it was believed to be impossible to separate the juice from fresh muscle material by even the highest pressures.

Evidently there is a large amount of preformed water in the body aside from that in the protein of flesh or gland. It must be borne in mind, however, that these conclusions are drawn from only one experiment, although it

[187] O. v. Fürth, Beiträge zur chem. Physiol. u. Pathol. (1903), 3, p. 543; Schmidt-Nielson, Beiträge zur chem. Physiol. u. Pathol. (1903), 4, p. 182.

should also be added that the results on the fifth day of experiment No. 73 indicate the gradual approach of the loss of water to that of the water in the flesh. The results of the fifth day of experiment No. 75 show a loss of preformed water less than that of preformed water in the flesh katabolized, so that the extremely close figures of the sixth and seventh days of the experiment may have been a coincidence. Nevertheless, the general trend of the experiments is to indicate an approaching equilibrium toward the end of a prolonged fast. It was thus seen that the excess of water in the body was practically all eliminated by about the fifth day of fasting, and that, thereafter, the loss of water was determined in large measure by the flesh katabolized.

It would be interesting to compute the water balance of experiments in which the period of inanition was much longer than any of these here reported. Unfortunately the exact data for such comparison are lacking.

As a result of these observations, and specifically the results obtained in experiment No. 75, it may be contended that the preformed water in the body exists in two forms, first, that which has a more or less fixed relation to the quantity of protein, and, second, a residuum of water retained in a manner not as yet clear. However definite the apparent proportion of protein and water in flesh during normal nutrition, Lichtenfelt [189] has shown that, at least with fish, during inanition there is a relatively increased amount of water in the flesh, and consequently the proportions of protein and water in flesh are by no means as fixed as the factors commonly used would imply. These experiments with fasting men imply that in addition to the water held as water of flesh, there is a very considerable residuum of water in the body. This residuum may be drawn upon during the early days of inanition. The ingestion of large amounts of water does not prevent its loss, although in numerous instances during a long period of inanition, when the amount of drinking-water was greatly increased, there was a marked retention of water by the body.

Several experiments point toward this view. For example, on the tenth and thirteenth days of Succi's fast in Naples, there were large quantities of water consumed with a very small elimination of urine.[190] It is reasonable to suppose that the muscular activity on these days was not greatly in excess of that on the preceding days, and he must have stored considerable amounts of water in the body. This observation has likewise been noted in a number of instances in experiments immediately following a fast.

It is unfortunate that the exact data have been recorded in no instances and the comparison is at best unsatisfactory. If water is stored in the body during

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[189] Loc. cit.

[190] In striking contrast to these results is the observation of Brugsch (12) that, while the drinking-water and urine excretion of Succi during the Hamburg fast had been constant at 750 cc. and 600 cc., respectively, on the thirteenth day the water of drink was increased to over 1000 cc. and simultaneously the urine increased by about a corresponding amount.

a fast it is clear that the tissues of the body have the power of absorbing and retaining water other than as water of flesh. Contrary to this view is the fact observed that there are no material variations in the density of the blood, and the exact place where this excess water accumulates is as yet unexplained.

If the deductions based upon experiment No. 75 are correct, it is especially interesting to note that, of all the factors of katabolism during inanition, the excretion of residuum water, other than that combined with the flesh, alone ceases on the sixth day. The katabolism of protein as shown by the experiments with Succi may continue for 30 or more days. Certainly there is a large amount of fat left in the body, even after prolonged inanition, and experiments on animals would imply that there are also small amounts of glycogen remaining in the body after prolonged inanition. Similarly, the skeleton may be drawn upon persistently throughout the whole of the fast, but the results of this 7-day experiment suggest that the residuum or excess water in the body is wholly eliminated by the end of a 5-day fast.

Effect of inanition on the proportion of water in the body.—Since the total katabolism is measured in these experiments, it is of interest to compare the losses of solid matter with those of water. From the data regarding the amounts of protein, fat, glycogen, and ash katabolized and preformed water lost from the body, the proportion of water to total solid matter leaving the body during inanition may be computed.

In table 230 are recorded the weights of solids katabolized, i. e., the amounts of protein, fat, glycogen, and ash, the loss of preformed water, and the per cent of the total loss due to water. The data are given only for the longer fasts.

The total weight of solid material katabolized may vary from 217 to 341 grams, while the loss of preformed water in these experiments ranges from 203 to 965 grams. In one instance, namely, on the first day of experiment No. 75, there was an absolute gain of preformed water to the body. The total loss may be as high as 1236 grams. An examination of the figures in the last column of the table shows that the per cent of total loss due to water varies within considerable limits, the lowest, 41.1 per cent, being on the third day of experiment No. 69, and the highest, 78.6, on the second day of experiment No. 77. The daily averages for the 5 experiments given in the table are 54.4, 62.0, 63.2, 59.6, and 75.3 per cent, respectively.

Since it is commonly assumed that the body contains approximately 60 per cent of water, it is seen that the proportions of water to solid matter in the material lost are not widely different from those occurring in the body.

In experiment No. 69, the per cent of water lost is much lower than the average (60 per cent) and in experiment No. 77 the loss is much larger (75.3 per cent). The fact that there was an actual gain of preformed water on the first day of experiment No. 75 would lower very considerably the proportion of the total loss due to water.

If the weight of the skeleton be deducted from that of the body the proportion of water in the flesh and other tissues is considerably greater than 60 per cent. Assuming such an increased percentage, from the relative amounts of water lost during inanition it would appear that the observations

TABLE 230.—*Proportion of total loss of flesh due to preformed water.*

Experiment number.	Subject and day of experiment.		Weight of solids katabolized.	Loss of preformed water.	Total loss.	Per cent of total loss due to water.
			Grams.	*Grams.*	*Grams.*	*Per cent.*
69	A.L.L.,	First day	306	286	592	48.3
		Second day	298	659	957	68.9
		Third day	291	203	494	41.1
		Fourth day	268	386	654	59.1
		Average	291	383	674	54.4
71	S.A.B.,	First day	341	[1] 440	780	56.4
		Second day	254	[1] 476	730	65.2
		Third day	249	[1] 564	813	69.3
		Fourth day	229	306	534	57.3
		Average	268	446	714	62.0
73	S.A.B.,	First day	314	[1] 618	932	66.3
		Second day	248	[1] 621	869	71.5
		Third day	235	[1] 349	584	59.8
		Fourth day	229	362	591	61.2
		Fifth day	225	300	525	57.3
		Average	250	450	700	63.2
75	S.A.B.,	First day	271	[2] −48	....	....
		Second day	263	564	816	69.1
		Third day	243	529	771	68.6
		Fourth day	247	453	700	64.7
		Fifth day	226	216	442	48.9
		Sixth day	222	255	476	53.6
		Seventh day	217	239	456	52.4
		Average	240	[3] 376	[3] 610	[3] 59.6
77	S.A.B.,	First day	294	[1] 942	1236	76.2
		Second day	263	[1] 965	1228	78.6
		Third day	273	927	1200	77.3
		Fourth day	257	578	835	69.2
		Average	272	853	1125	75.8

[1] Does not include water of feces.
[2] Gain. Water of feces not taken into account.
[3] Average of 6 days.

of Lichtenfelt[100] on the flesh of fish during inanition are likewise true for the flesh of fasting man, i. e., inanition results in an increase in the proportion of water in the body.

[100] Loc. cit.

ENERGY.

In common with all living organisms, fasting man is constantly producing and giving off heat as a result of katabolism. The amounts of heat produced, the source of the energy, the factors influencing heat production, and all allied topics have an unusual interest when studied with fasting man.

Likhachev[161] experimented on a man fasting for 24 hours in the Pashutin respiration apparatus modified so as to permit the direct measurements of heat.

It has been necessary in all other inanition experiments to compute the energy transformations from the data for the total katabolism, and since there was no means of ascertaining whether the katabolized material other than protein consisted of fat or glycogen, it was assumed that it was all fat. Hence, the computations of the energy transformations were subject to all the errors incidental to the determination of the amounts of katabolized protein and fat. The measure of the protein katabolism was essentially that used in the present day, but we have seen from the foregoing discussions that the amounts of fat katabolized as computed from the total carbon output and the carbon of protein are materially different from those determined by the present method, in which the direct measurement of the oxygen consumption permits an apportionment of the total katabolism as protein, fat, and glycogen. The oxidation of one gram of carbon in the form of glycogen gives rise to much less heat than the oxidation of one gram of carbon in the form of fat, and hence the energy transformations computed on the assumption that only fat and protein were burned in the body must of necessity be erroneous.

In the experiments here reported, not only were the total amounts of katabolized protein, fat, and glycogen computed, but the type of apparatus also permitted direct determinations of the amounts of heat eliminated. Since there were varying amounts of heat residual in the body at the end of the different days of the different experiments, corrections were applied to the heat elimination to obtain the actual heat production. (See discussion, p. 46.)

For the purpose of comparing the estimated energy derived from material oxidized in the body, the heat production rather than the heat elimination must be used. Heat elimination will first be considered in the following discussion, and then the heat production. Aside from the kinetic energy leaving the body there are considerable amounts of potential energy excreted in the unoxidized material of the urine. For this reason, a particular section of the report is reserved for the discussion of the energy of the urine.

HEAT ELIMINATION.

The calorimetric features of the respiration calorimeter were devised for the special purpose of measuring directly the heat eliminated by man.

The tests of the accuracy of the apparatus have been numerous and severe, and in practically every instance, the results obtained have been all that could

[161] Dissertation, Russian (1893), St. Petersburg.

be desired, indicating an error of somewhat less than 1 per cent. Difficulties attending the control of the temperature of the room in which the experiments have been made and minor discrepancies in the manipulation of the apparatus by assistants with varying degrees of skill have undoubtedly introduced errors of slight magnitude that are not compensated and are not absolutely known. It is believed that in a large majority of the experiments here reported, the accuracy of the heat measurement is well within 1 per cent. In some instances the error may be greater than this but in no case could it have amounted to 5 per cent.

Heat can leave the body in a number of different ways. The larger portion of the heat is lost by radiation and conduction; a certain amount is used to warm the inspired air; the urine and feces carry away measurable amounts of heat; finally large quantities are necessary to vaporize the water eliminated from the lungs and surface of the body. Aside from the measurement of these factors, there are the numerous corrections which have to deal with the actual heat production during the period of the study, corrections which receive special subsequent treatment.

The heat lost by radiation and conduction, together with that required to warm the inspired air is measured by the amount of water passing through the heat absorbers and the temperature through which this water is raised. The amount of heat thus measured, however, includes also the heat lost from the urine and feces that are allowed to cool to the temperature of the calorimeter before being removed. From the weights and specific heats of urine and feces and the difference between the body temperature and the temperature of the calorimeter, the amount of heat lost by this means can be computed. It is recorded for the experiments here published in table 231, column *c*. The amount of heat required to warm the inspired air from the temperature of the calorimeter to that of the body may be obtained by the use of four factors: the total ventilation of the lungs, the weight of a liter of air, the specific heat of air, and the difference between the temperature of the calorimeter and that of the body. The volume of the inspired air has been computed and the total ventilation of the lungs is given in column *a* of table 220. Since these results are recorded in liters reduced to standard conditions of temperature and pressure, the weight of air warmed is obtained by multiplying the total ventilation by 1.293, the weight of a liter of air at standard conditions of temperature and pressure. From the weight of air, its specific heat[188] and the difference between the body temperature and that of the chamber, the amount of heat actually required to warm this inspired air may readily be computed.

Deducting from the total heat brought away by the water current the heat from the feces and urine and that required to warm the inspired air, leaves the heat of radiation and conduction, which is recorded in the first column of table 231.

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[188] The specific heat of air has been taken as 0.237.

TABLE 231.—*Heat eliminated by the body in different ways, amounts per day, and proportions of total in metabolism experiments with and without food.*

Experiment number.	Subject and date.	Quantities of heat per day.							Proportion of total for 24 hours.					
		Heat eliminated.						(g) Total for 24 hours.	Heat eliminated.					
		(a) By radiation and conduction.	(b) Required to warm inspired air.	(c) In urine and feces.	In water vaporized from lungs and skin.				(h) By radiation and conduction.	(i) Required to warm inspired air.	(j) In urine and feces.	In water vaporized from lungs and skin.		
					(d) From lungs.	(e) From skin.	(f) Total.					(k) From lungs.	(l) From skin.	(m) Total.
	Experiments without food.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
59.	B. F. D.: Dec. 18-19, 1903......	1453	48	26	194	388	582	2109	68.9	2.3	1.2	9.2	18.4	27.6
	Dec. 19-20, 1903......	1475	48	16	196	368	564	2103	70.1	2.3	.8	9.3	17.5	26.8
	Dec. 20-21, 1903......	1486	50	16	203	355	558	2110	70.4	2.4	.8	9.6	16.8	26.4
68........	A. L. L.: Apr. 27-28, 1904......	1668	49	17	195	246	441	2175	76.7	2.3	.8	9.0	11.3	20.3
	Apr. 28-29, 1904......	1704	49	15	196	254	450	2218	76.8	2.2	.7	8.8	11.5	20.3
69........	A. L. L.: Dec. 16-17, 1904......	1467	45	7	182	255	437	1956	75.0	2.3	.4	9.3	13.0	22.3
	Dec. 17-18, 1904......	1583	49	10	195	337	532	2174	72.8	2.3	.4	9.0	15.5	24.5
	Dec. 18-19, 1904	1525	47	13	190	281	471	2056	74.2	2.3	.6	9.2	13.7	22.9
	Dec. 19-20, 1904......	1482	46	12	188	243	431	1971	75.2	2.3	.6	9.6	12.3	21.9
71........	S. A. B.: Jan. 7- 8, 1905......	1445	45	22	183	258	441	[1]1968	73.4	2.3	1.1	9.3	13.1	22.4
	Jan. 8- 9, 1905......	1383	42	32	179	215	394	1851	74.7	2.3	1.7	9.7	11.6	21.3
	Jan. 9-10, 1905......	1335	41	41	177	159	336	1753	76.2	2.3	2.3	10.1	9.1	19.2
	Jan. 10-11, 1905......	1253	38	23	163	143	306	1620	77.4	2.3	1.4	10.1	8.8	18.9
73.......	S. A. B.: Jan. 28-29, 1905......	1398	42	37	177	228	405	1882	74.3	2.2	2.0	9.4	12.1	21.5
	Jan. 29-30, 1905......	1334	42	48	182	195	377	1801	74.1	2.3	2.7	10.1	10.8	20.9
	Jan. 30-31, 1905......	1309	41	44	177	180	357	1751	74.8	2.3	2.5	10.1	10.3	20.4
	Jan. 31-Feb. 1, 1905.	1266	39	31	169	168	337	1673	75.7	2.3	1.9	10.1	10.0	20.1
	Feb. 1- 2, 1905......	1181	37	16	164	158	322	1556	75.9	2.4	1.0	10.5	10.2	20.7
75.......	S. A. B.: Mar. 4- 5, 1905......	1316	41	24	176	209	385	1766	74.5	2.3	1.4	10.0	11.8	21.8
	Mar. 5- 6, 1905......	1321	41	30	179	201	380	1772	74.6	2.3	1.7	10.1	11.3	21.4
	Mar. 6- 7, 1905......	1366	41	35	179	210	389	1831	74.6	2.2	1.9	9.8	11.5	21.3
	Mar. 7- 8, 1905......	1351	40	31	175	178	353	1775	76.1	2.3	1.7	9.9	10.0	19.9
	Mar. 8- 9, 1905......	1251	38	23	166	177	343	1655	75.6	2.3	1.4	10.0	10.7	20.7
	Mar. 9-10, 1905......	1183	36	25	160	161	321	1565	75.6	2.3	1.6	10.2	10.3	20.5
	Mar. 10-11, 1905......	1185	36	25	159	162	321	1567	75.6	2.3	1.6	10.2	10.3	20.5

77	S. A. B.:	Apr. 8-9, 1905	1412	48	41	185	211	396	1898	74.6	2.3	2.2	9.8	11.1	20.9
		Apr. 9-10, 1905	1437	44	34	190	188	378	1893	75.9	2.3	1.8	10.1	9.9	20.0
		Apr. 10-11, 1905	1429	41	24	177	189	366	1860	76.8	2.2	1.8	9.5	10.2	19.7
		Apr. 11-12, 1905	1389	41	18	178	193	371	1819	76.8	2.3	1.0	9.8	10.6	20.4
79	H. E. S.:	Oct. 13-14, 1905	1479	44	17	169	226	395	1935	76.4	2.3	.9	8.7	11.7	20.4
		Oct. 14-15, 1905	1571	46	14	174	243	417	2048	76.7	2.2	.7	8.5	11.9	20.4
80	C. R. Y.:	Oct. 27-28, 1905	1340	44	19	173	376	549	1952	68.6	2.3	1.0	8.9	19.2	28.1
		Oct. 28-29, 1905	1428	48	13	187	441	628	2113	67.4	2.3	.6	8.8	20.9	29.7
81	A. H. M.:	Nov. 21-22, 1905	1315	40	10	172	188	360	1725	76.2	2.3	.6	10.0	10.9	20.9
		Nov. 22-23, 1905	1331	40	13	175	222	397	1781	74.7	2.3	.7	9.8	13.5	22.3
82	H. C. K.:	Nov. 24-25, 1905	1685	51	9	213	286	499	2244	75.1	2.3	.4	9.5	12.7	22.2
		Nov. 25-26, 1905	1833	56	31	233	324	557	2476	74.0	2.3	1.2	9.4	13.1	22.5
83	H. R. D.:	Dec. 5-6, 1905	1436	45	18	193	213	405	1904	75.4	2.4	.9	10.1	11.2	21.3
		Dec. 6-7, 1905	1457	42	16	183	215	398	1913	76.2	2.2	.8	9.6	11.2	20.8
85	N. M. P.:	Dec. 9-10, 1905	1574	48	19	204	255	459	2100	74.9	2.3	.9	9.7	12.2	21.9
		Dec. 10-11, 1905	1747	52	11	215	267	482	2292	76.2	2.3	.5	9.4	11.6	21.0
89	D. W.:	Jan. 10-11, 1906	1625	49	10	207	278	485	2169	74.9	2.3	.5	9.5	12.8	23.3
		Jan. 11-22, 1906	1738	53	8	218	257	475	2273	76.4	2.3	.4	9.6	11.8	20.9
	Average of experiments without food		1440	44	22	185	239	424	1981	74.6	2.3	1.1	9.6	12.4	22.0
	Experiments with food.														
70	A. L. L.:	Dec. 20-21, 1904	1551	48	17	193	304	497	2118	73.4	2.3	.8	9.1	14.4	23.5
		Dec. 21-22, 1904	1516	51	17	206	388	594	2178	69.6	2.3	.8	9.5	17.8	27.3
		Dec. 22-23, 1904	1709	56	13	222	405	627	2405	71.1	2.3	.5	9.2	16.9	26.1
72	S. A. B.:	Jan. 11-12, 1905	1288	40	25	171	152	323	1676	76.8	2.4	1.5	10.2	9.1	19.3
74	S. A. B.:	Feb. 2-3, 1905	1278	39	25	171	175	346	1688	75.7	2.3	1.5	10.1	10.4	20.5
		Feb. 3-4, 1905	1200	37	32	164	148	312	1561	76.0	2.3	2.0	10.4	9.3	19.7
		Feb. 4-5, 1905	1228	38	27	165	146	311	1604	76.5	2.3	1.7	10.3	9.1	19.4
76	S. A. B.:	Mar. 11-12, 1905	1329	40	28	178	187	365	1762	75.4	2.3	1.6	10.1	10.6	20.7
		Mar. 12-13, 1905	1324	38	21	170	175	345	1728	76.6	2.2	1.2	9.9	10.1	20.0
		Mar. 13-14, 1905	1320	39	26	172	190	362	1747	75.6	2.2	1.5	9.8	10.9	20.7
	Average of experiments with food		1374	43	23	181	227	408	1848	74.7	2.3	1.2	9.8	12.3	22.1

[1] Includes heat equivalent of external muscular work in revolutions of ergometer. Corrected for 3 calories due to magnetization of fields of ergometer. Heat equivalent of external muscular work, 15 calories; per cent 0.8.

The heat of vaporization of water is taken as 0.592 calorie per gram, and by means of this factor and the weight of water vaporized from the body, the energy absorbed by the water is computed. The weights of water vaporized from the lungs and skin are recorded in columns *d* and *e* of table 220, and the energy absorbed in their vaporization is recorded in columns *d* and *e*, of table 231, the total heat required to vaporize all the water being recorded in column *f*.

The total heat elimination for the different days of the experiment is recorded in column *g*. It is to be noted that these values are not identical with those given elsewhere for the total heat production, and it must be borne in mind that heat elimination, as distinguished from the heat production, is here under discussion. The proportions of the total heat eliminated from the body in the various ways have been computed and recorded in columns *h* to *m* inclusive.

From these data, it may be seen that not far from 75 per cent of the total heat eliminated leaves the body by radiation and conduction; 2.3 per cent is utilized in warming the inspired air; as a rule less than 2 per cent is given up by the excreta; about 10 per cent is required to vaporize the water from the lungs; and 12 per cent is required to vaporize the water from the skin.

The individual fluctuations from these averages are noticeable chiefly in the heat of urine and feces, which is to be expected from the marked variations in the volume of urine excreted. All the other factors, while varying somewhat, are relatively constant, and the average of these experiments with fasting men at rest shows that 1440 calories are eliminated by radiation and conduction, 44 calories are required to warm the inspired air, 22 calories are given off by the urine and feces, 424 calories appear in the water vaporized from the lungs and skin, the total average heat elimination being 1931 calories.

No noticeable abnormalities are to be observed in the similar data for the experiments with food.

HEAT PRODUCTION

In the katabolism of protein, fat, and glycogen during inanition, heat is produced. A comparison of the heat production with the katabolism can not be made by simply measuring the heat lost from the body through radiation, conduction, and vaporization of water. The principles involved in the computation of this production as distinguished from the heat elimination have already been discussed in considerable detail in connection with experiment No. 59 (see p. 46). It is only necessary to call to mind here that changes in body-weight and body temperature are theoretically at least of great importance in determining the heat production as distinguished from the heat elimination. As the fast progresses, the body loses weight. The material lost is cooled from the temperature of the body to the temperature of the calorimeter, but the

heat given off by the cooling of this material does not represent heat actually produced from katabolism. The discussion which follows deals specifically with heat production and takes into account, therefore, the heat elimination corrected for energy gained or lost because of changes of body-weight and body temperature. The results for the measured heat production are recorded for all experiments without food in table 232, together with the distribution of rates and proportions over the main periods of the day.

By a comparison of the first column of table 232, which gives the total heat production in 24 hours, with column *g* of table 231, which gives the total heat elimination, some conception can be had of the variations due to the corrections for changes in body temperature, body-weight, etc. It is surprising how slight is the variation between the different experiments. Thus, the average heat production for all the fasting experiments is 1924 calories, while the heat elimination for the same series is 1931 calories. It might seem that the heat elimination may be taken as the measure of the heat production, and indeed in fasting experiments the correctness of this assumption is fairly well established, since the corrections for the heat production are more or less compensating. When the data for shorter periods are desired, however, it is of extreme importance that the heat production rather than the heat elimination be used. The heat production and heat elimination in experiment No. 59 were determined not only for the 24 hours but also for the 3-hour periods (see table 17). The differences between the heat production and heat elimination for 3-hour periods are much more marked than for the day.

The distribution of the heat production over the 6-hour periods has been computed and given in table 232. The proportion of the total heat in 24 hours produced for each period has likewise been calculated and recorded in the table. As is to be expected the greater amount is produced during the day period. This is in harmony with the conception that muscular activity determines in large measure the heat production, for even though these are distinctively rest experiments, the muscular activity is obviously greater in the day time than at night. The fact that in some of the experiments the subjects spent not a little time sleeping during the day would, however, tend to more nearly equalize the heat production of the first 12 hours of the day with the last twelve. Reference to the detailed records of the body movements will show during which hours the subject was asleep. The results show that the heat during the last period of the night, i. e., from 1 a. m. to 7 a. m. is more nearly uniform on the different days of the fasting experiments than during any other period. However, there is, as a rule, a decrease in heat production during this period of the night as the fast progresses.

The irregularities in muscular activity in the day time render any comparison of the different experiments, and indeed different days of the same experiment, extremely difficult. It is only by taking into account the total sum of body

TABLE 232.—*Heat production of body, amounts per day and per hour, and proportions for different periods—Metabolism experiments without food.*

Experiment number.	Subject and date.	Total am'nt in 24 hours.	Rate per hour. Day periods. 7 a. m. to 1 p. m.	Rate per hour. Day periods. 1 to 7 p. m.	Rate per hour. Night periods. 7 p. m. to 1 a. m.	Rate per hour. Night periods. 1 to 7 a. m.	Rate per hour. Average for 24 hours	Proportion of total for 24 hours. Day periods. 7 a. m. to 1 p. m.	Proportion of total for 24 hours. Day periods. 1 to 7 p. m.	Proportion of total for 24 hours. Night periods. 7 p. m. to 1 a. m.	Proportion of total for 24 hours. Night periods. 1 to 7 a. m.
		Cals.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
59..	B.F.D., 1903:										
	Dec. 18–19.....	2080	102	95	79	71	87	29.4	27.4	22.8	20.4
	Dec. 19–20.....	2107	98	91	87	75	88	27.9	25.9	24.8	21.4
	Dec. 20–21.....	2102	97	91	88	79	88	27.7	26.0	23.7	22.6
	Total........	6289	297	277	249	225	263	....	....	....	....
	Av. per day..	2096	99	92	83	75	88	28.4	26.4	23.7	21.5
68..	A.L.L., 1904:										
	Apr. 27–28.....	2167	100	96	93	72	90	27.7	26.6	25.8	19.9
	Apr. 28–29.....	2217	98	99	91	82	92	26.5	26.8	24.6	22.1
	Total........	4384	198	195	184	154	182	....	....	....	....
	Av. per day..	2192	99	98	92	77	91	27.1	26.8	25.1	21.0
69..	A.L.L., 1904:										
	Dec. 16–17.....	1951	78	93	78	76	91	24.0	28.6	24.0	23.4
	Dec. 17–18.....	2163	91	105	89	76	90	25.2	29.1	24.7	21.0
	Dec. 18–19.....	2035	92	95	89	63	85	27.1	28.0	26.3	18.6
	Dec. 19–20.....	1958	86	89	81	70	81	26.4	27.3	24.8	21.5
	Total........	8107	347	382	337	285	337	....	....	....	....
	Av. per day..	2027	87	96	84	71	84	25.7	28.4	24.9	21.0
71..	S.A.B., 1905:										
	Jan. 7– 8.....	1970	115	85	69	59	82	35.1	25.9	21.0	18.0
	Jan. 8– 9.....	1844	98	76	68	65	77	31.9	24.8	22.1	21.2
	Jan. 9–10.....	1746	83	81	67	60	73	28.6	27.8	23.0	20.6
	Jan. 10–11.....	1606	79	71	59	58	67	29.6	26.6	22.1	21.7
	Total........	3166	375	313	263	242	299	....	....	....	....
	Av. per day..	1792	94	78	66	61	75	31.4	26.1	22.1	20.4
73..	S.A.B., 1905:										
	Jan. 28–29.....	1866	94	82	68	66	78	30.3	26.5	21.9	21.3
	Jan. 29–30.....	1791	89	81	66	62	75	29.9	27.2	22.1	20.8
	Jan. 30–31.....	1739	85	83	64	58	72	29.3	28.6	22.1	20.0
	Jan. 31–Feb.1..	1663	81	75	61	59	69	29.3	27.2	22.1	21.4
	Feb. 1– 2.....	1548	73	66	62	56	65	28.4	25.7	24.1	21.8
	Total........	8607	422	387	321	301	359	....	....	....	....
	Av. per day..	1721	84	77	64	60	72	29.5	27.0	22.5	21.0
75..	S.A.B., 1905:										
	Mar. 4– 5.....	1765	89	72	66	67	74	30.3	24.5	22.4	22.8
	Mar. 5– 6.....	1768	89	76	66	63	74	30.3	25.9	22.4	21.4
	Mar. 6– 7.....	1797	87	85	63	64	75	29.1	28.4	21.1	21.4
	Mar. 7– 8.....	1775	87	81	65	63	74	29.4	27.3	22.0	21.3
	Mar. 8– 9.....	1649	80	76	60	59	69	29.1	27.6	21.8	21.5
	Mar. 9–10.....	1553	77	68	58	56	65	29.7	26.3	22.4	21.6
	Mar. 10–11.....	1568	77	71	57	56	65	29.5	27.2	21.8	21.5
	Total........	11875	586	529	435	428	496	....	....	....	....
	Av. per day..	1696	84	76	62	61	71	29.7	26.9	21.9	21.5

TABLE 232.—*Heat production of body, amounts per day and per hour, and proportions for different periods—Metabolism experiments without food*—Continued.

Experiment number.	Subject and date.	Total am'nt in 24 hours.	Rate per hour.					Proportion of total for 24 hours.			
			Day periods.		Night periods.		Average for 24 hours	Day periods.		Night periods.	
			7 a. m. to 1 p. m.	1 to 7 p. m.	7 p. m. to 1 a. m.	1 to 7 a. m.		7 a. m. to 1 p. m.	1 to 7 p. m.	7 p. m. to 1 a. m.	1 to 7 a. m.
77..	S.A.B., 1905:	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Apr. 8- 9.....	1874	90	84	67	71	78	28.8	26.9	21.5	22.8
	Apr. 9-10.....	1880	82	85	72	75	78	26.1	27.1	22.9	23.9
	Apr. 10-11.....	1840	79	80	70	78	77	25.7	26.1	22.8	25.4
	Apr. 11-12.....	1807	75	79	71	76	75	24.9	26.2	23.6	25.3
	Total........	7401	326	328	280	300	308	....	....	....	....
	Av. per day..	1850	82	82	70	75	77	26.5	26.5	22.7	24.3
79..	H.E.S., 1905:										
	Oct. 13-14.....	1951	88	79	82	77	81	27.0	24.2	25.2	23.6
	Oct. 14-15.....	2047	89	87	84	81	85	26.1	25.5	24.6	23.8
	Total	3998	177	166	166	158	166	....	....	....	....
	Av. per day..	1999	89	83	83	79	83	26.6	24.9	24.9	23.6
80..	C.R.Y., 1905:										
	Oct. 27-28.....	1954	88	75	82	81	81	27.0	23.0	25.2	24.8
	Oct. 28-29.....	2099	99	89	81	82	87	28.2	25.4	23.1	23.3
	Total........	4053	187	164	163	163	168	....	....	....	....
	Av. per day..	2027	94	82	82	82	84	27.7	24.1	24.1	24.1
81..	A.H.M., 1905:										
	Nov. 21-22.....	1729	81	82	66	59	72	28.1	28.5	22.9	20.5
	Nov. 22-23.....	1781	90	69	71	67	74	30.3	23.2	23.9	22.6
	Total........	3510	171	151	137	126	146	....	....	....	....
	Av. per day..	1755	86	76	69	63	73	29.3	25.8	23.5	21.4
82..	H.C.K., 1905:										
	Nov. 24-25.....	2222	107	88	97	78	93	28.9	23.8	26.2	21.1
	Nov. 25-26.....	2477	118	101	106	88	103	28.6	24.4	25.7	21.3
	Total........	4699	225	189	203	166	196	....	....	....	....
	Av. per day..	2350	113	95	102	83	98	28.8	24.2	25.9	21.1
83..	H.R.D., 1905:										
	Dec. 5-6......	1914	94	64	89	71	80	29.6	20.1	28.0	22.3
	Dec. 6-7......	1907	98	68	80	72	79	30.8	21.4	25.2	22.6
	Total........	3821	192	132	169	143	159	....	....	....	....
	Av. per day..	1911	96	66	85	72	80	30.1	20.7	26.6	22.6
85..	N.M.P., 1905:										
	Dec. 9-10.....	2109	99	84	89	79	88	28.2	23.9	25.4	22.5
	Dec. 10-11.....	2305	106	93	99	86	96	27.6	24.2	25.8	22.4
	Total........	4414	205	177	188	165	184	....	....	....	....
	Av. per day..	2207	103	89	94	83	92	27.9	24.1	25.5	22.5
89..	D.W., 1906:										
	Jan. 10-11.....	2150	80	101	95	82	90	22.4	28.2	26.5	22.9
	Jan. 11-12.....	2254	88	105	104	78	94	23.5	28.0	27.7	20.8
	Total........	4404	168	206	199	160	184	....	....	....	....
	Av. per day..	2202	84	103	100	80	92	22.9	28.1	27.2	21.8
	Av. of experiments without food...	1924	90	84	77	70	80	28.0	26.2	24.0	21.8

movements that any intelligent comparison can be made. In fasting experiments such as those here reported, in which the subjects were distinctly inactive, the proportions of the total heat for 24 hours are about evenly divided among the periods. The average of all the fasting experiments shows that 28 per cent of the heat was produced between 7 a. m. and 1 p. m., 26.2 per cent between 1 and 7 p. m., 24 per cent from 7 p. m. to 1 a. m., and 21.8 per cent from 1 to 7 a. m.

When these men were asleep the heat production per hour averaged 70 calories. Considerable variations in the quantities produced per hour may be observed, not only with different subjects, but with the same subjects in different experiments. The unusually large production of 115 calories of heat per hour during the first period of the first day of experiment No. 71 is due to the fact that during this period the subject rode for 10 minutes on the bicycle ergometer. In no other period with this subject did the heat production rise to over 98 calories per hour. The lowest heat production recorded in any experiment was 56 calories per hour. This small amount was produced in the last period of the last day of the two longest experiments, Nos. 73 and 75. In explanation of these irregularities reference must be made to the notes in the diaries of the subjects and records of body movements previously recorded and to the estimates of muscular activity given beyond.

Heat production per kilogram of body-weight and per square meter of body surface.—The irregularities in the heat production noted in the fasting experiments reported herewith may be accounted for in several ways: First, there may be marked differences in muscular activity. This factor receives special discussion elsewhere (see p. 484). Second, there may be a difference in size of the different subjects and consequently the total heat production per kilogram of body-weight is of value in comparing the different experiments. For other comparisons commonly made by physiologists, the production per square meter of body surface is likewise of value.

The heat produced per kilogram of body-weight and per square meter of body surface has been computed for all of these fasting experiments and is recorded in table 233. The results for the food experiments Nos. 70, 72, 74, and 76 are also included in the table.

The average heat production per kilogram of body-weight for the first day of the 18 experiments with and without food was 30.7 calories. The range is from 26.6 to 34.6 calories, but the results in the large majority of the experiments were very close to the general average. On the second day the average is over 1 calorie greater, i. e., 31.8. The fluctuations range from 28.6 to 36.9 calories. The average heat production per kilogram of body-weight on the third day is 31.0 calories and on the fourth, fifth, sixth, and seventh days, the averages are 29.6, 28.5, 27.5, and 28.0 calories, respectively. There is, then, a distinct tendency for the heat (per kilogram of body-weight) to decrease after the second day.

TABLE 233.—*Heat produced per kilogram of body-weight and per square meter of body surface in metabolism experiments with and without food.*

Experiment number.	Subject and date.		First day.	Second day.	Third day.	Fourth day.	Fifth day.
			Cals.	Cals.	Cals.	Cals.	Cals.
59..	B.F.D., Dec. 18 to 19, 1903...	Per kilo......	31.0	31.9	32.1	....	....
		Per sq. meter..	**1023**	**1046**	**1050**	....	....
68..	A.L.L., Apr. 27 to 28, 1904...	Per kilo......	30.1	31.3	....	....	....
		Per sq. meter..	**1017**	**1052**	....	....	....
69..	A.L.L., Dec. 16 to 19, 1904...	Per kilo......	26.6	29.8	28.3	27.5	....
		Per sq. meter..	**903**	**1009**	**956**	**924**	....
70..	A.L.L., Dec. 20 to 22, 1904...	Per kilo......	29.7	31.4	34.8	....	....
		Per sq. meter..	**988**	**1056**	**1168**	....	....
71..	S.A.B., Jan. 7 to 10, 1905...	Per kilo......	34.2	32.4	31.0	28.9	....
		Per sq. meter..	**1072**	**1023**	**964**	**895**	....
72..	S.A.B., Jan. 11, 1905........	Per kilo......	30.4	....	....	....	....
		Per sq. meter..	**940**	....	....	....	....
73..	S.A.B., Jan. 28 to Feb. 1, 1905	Per kilo......	31.9	31.1	30.6	29.7	28.0
		Per sq. meter..	**1005**	**975**	**955**	**922**	**866**
74..	S.A.B., Feb. 2 to 4, 1905...	Per kilo......	30.7	28.6	28.9	....	....
		Per sq. meter..	**949**	**886**	**895**	....	....
75..	S.A.B., Mar. 4 to 10, 1905...	Per kilo[1].....	29.7	29.9	30.8	30.8	29.0
		Per sq. meter[2].	**941**	**946**	**969**	**966**	**985**
76.	S.A.B., Mar. 11 to 13, 1905...	Per kilo......	31.7	31.0	31.2	....	....
		Per sq. meter..	**984**	**961**	**971**	....	....
77..	S.A.B., Apr. 8 to 11, 1905...	Per kilo......	30.6	31.2	31.2	31.3	....
		Per sq. meter..	**980**	**993**	**987**	**982**	....
79..	H.E.S., Oct. 13 to 14, 1905...	Per kilo......	34.5	36.9	....	....	....
		Per sq. meter..	**1075**	**1143**	....	....	....
80..	C.R.Y., Oct. 27 to 28, 1905...	Per kilo......	28.5	31.5	....	....	....
		Per sq. meter..	**948**	**1037**	....	....	....
81..	A.H.M., Nov. 21 to 22, 1905...	Per kilo......	28.1	29.5	....	....	....
		Per sq. meter..	**901**	**939**	....	...	....
82..	H.C.K., Nov. 24 to 25, 1905...	Per kilo......	31.2	35.3	....	....	....
		Per sq. meter..	**1050**	**1183**	...	....	....
83..	H.R.D., Dec. 5 to 6, 1905...	Per kilo......	34.6	34.9	....	....	....
		Per sq. meter..	**1070**	**1075**	....	....	....
85..	N.M.P., Dec. 9 to 10, 1905...	Per kilo......	31.5	35.1	....	....	....
		Per sq. meter..	**1039**	**1149**	....	...	....
89..	D.W., Jan. 10 to 11, 1906...	Per kilo......	27.5	29.3	....	....	....
		Per sq. meter..	**945**	**1011**	....	....	....
	Average....	Per kilo body-weight......	30.7	31.8	31.0	29.6	28.5
		Per sq. meter body surface..	**992**	**1028**	**991**	**938**	**885**

[1] Values for the sixth and seventh days are 27.5 and 28.0 calories respectively.
[2] Values for the sixth and seventh days are 857 and 869 calories respectively.

Since the formula for computing body surface is dependent upon body-weight, the fluctuations observed in the heat production per kilogram of body-weight likewise appear when computed on the basis of per square meter of body surface. The average production per square meter of body surface on

the first day of all the experiments was 992 calories. On the second day the average was somewhat higher, 1028 calories, while on the third day, it was noticeably less, 991 calories. The averages for the fourth, fifth, sixth, and seventh days were 938, 885, 857, and 869 calories, respectively. These results show in general a tendency for the heat production per square meter of body surface to diminish after the second day of fasting. The presence of results for food experiments in the calculations (aside from those for experiment No. 70) has no material influence on the trend of the averages. While the constancy of the heat production per square meter of body surface in all classes of animals has been emphasized in many discussions, it may be observed that even with fasting man at rest, there are marked fluctuations in this factor, and here again variations in internal and external muscular activity may account for these seeming discrepancies in the heat production per square meter of body surface.

MUSCULAR ACTIVITY.

This series of experiments was made upon fasting men at muscular rest, and yet as has been repeatedly emphasized in the discussion, there were varying degrees of minor muscular activity during the experiments and it can not be said that the subjects all remained in the same degree of rest. Knowing the marked influence of excessive muscular activity on the heat production as observed in experiments on muscular work, it is important to determine, if possible, to what extent the slight variations in activity observed in these experiments influenced the heat production.

Method of estimating energy of external muscular activity.—Aside from the intermittent strength tests with the dynamometer in some of the experiments and the 10-minute exercise period on the bicycle ergometer on the first day of experiment No. 71, no measurement of the muscular activity of the subjects was attempted. Our knowledge regarding the energy required to perform the minor movements of the body, even in a so-called "rest experiment" is as yet very meager. But since it was important to estimate as nearly as possible the muscular activity on the different days and with the different subjects, a method for estimating these variations in activity has been put in use, although admittedly based on very uncertain evidence. The muscular activity was in general very slight. The visible muscular activity of the subjects was carefully recorded by the observer outside of the calorimeter chamber, the number of times the food aperture was opened and closed was likewise noted on a sheet provided for the purpose, and from the diary kept by the subject, records of certain other movements were obtained. These have been combined as has been shown previously in the "body movement" records for each experiment. From these movements the attempt has been made to estimate the muscular activity, expressed in calories. The material used con-

sisted of the records of body movements, the results obtained from a long series of unpublished experiments with different subjects to ascertain the energy required for certain definite motions, and an experiment made to find the energy required to rise from the chair, go to the food aperture, open it, close it, return and sit. Other motions than those which would naturally accompany the act of going to the food aperture were made by the different subjects in the fasting experiments and indeed in considerable number.

For the purpose of these estimates, one of the simplest motions, i. e., the act of rising from the chair in which the subject sits, is taken as a unit of movement, and all other movements are expressed in terms of this unit. The actual amount of energy required to go to the food aperture and return has been found from a series of special experiments to be one calorie. In another series, the energy required to undress, be weighed in a hanging chair, dress, and be seated was actually measured. This was found to average 20 calories. The operation at the food aperture was estimated to be 4 times as great as that of rising from the chair. Hence the unit of movement was taken as one-fourth of a calorie. With this as a basis, values were estimated for all the individual movements recorded in the unpublished experiments, the sum of which equaled 20 calories or 80 units. For example, the act of hanging the chair for weighing was estimated to be 5½ units; weighing, 3 units; hanging curtain and taking it down, 2 units; undressing, 16 units; dressing, 25½ units. It is to be noted that a greater total is given for the movements in dressing than in undressing, and estimates were likewise made for different acts in the process of the two operations.

Other movements occurring during the experiments are estimated according to their character, such as for example, to rise, weigh, and dress in the morning. To rise from the bed is reckoned as 3 units; hang chair, 5½ units; weigh, 3 units; remove and reinsert the rubber stopper through which the weighing rod passes to the top of the calorimeter, 1 unit; weigh clothing, 6 units; weigh the heat absorbers, 15 units; unhang chair, 5½ units; arrange and fold bed, 5 units; raise table, 3 units; dress (underclothing being already on), 15 units; sit down, 1 unit; total, 63 units.

Similarly, to prepare for bed at night, defecate, take the dynamometer test, and numerous other movements are each accorded their different estimated value in terms of these units.

In addition to the activity estimated for the first day of experiment No. 71, account should be taken of the bicycle ride during the second (9 to 11 a. m.) period of the day. Previous calibration has shown that each revolution of the wheel of the bicycle ergometer results in the transformation of 0.0233 calorie of heat, and as the wheel made 643 revolutions during the ride, the energy given off equals 643×0.0233. The result of this calculation $\times$ 5, since the efficiency of the body as a machine is about 20 per cent, = 74.91 calories, the total result for the ride.

In experiment No. 76, at 8^h 2^m p. m. March 11, 1905, gymnastics are estimated arbitrarily as 30 units. A walk in the chamber at 11^h 16^m a. m. January 8, 1905, in experiment No. 71, is estimated at 10 units.

TABLE 234.—*Estimate of visible muscular activity in metabolism experiments with and without food.*

Experiment number.	Subject and date of experiment.	(a) Estimated muscular activity.	(b) Energy of estimated muscular activity.	Experiment number.	Subject and date of experiment.	(a) Estimated muscular activity.	(b) Energy of estimated muscular activity.
59....	B.F.D., 1903:	*Units.*	*Cals.*	76....	S.A.B., 1905:	*Units.*	*Cals.*
	Dec. 18–20......	182	46		Mar. 11–13......	244	61
		160	40			166	42
		150	38			203	51
68....	A.L.L., 1904:			77....	S.A.B., 1905:		
	Apr. 27–28......	229½	57		Apr. 8–11.......	167½	42
		265	66			239	60
69....	A.L.L., 1905:					158	40
	Dec. 16–19......	109	27			215	54
		122	31	79....	H.E.S., 1905:		
		128	32		Oct. 13–14......	199	50
		133	33			174	44
70....	A.L.L., 1905:			80....	C.R.Y., 1905:		
	Dec. 20–22......	129	32		Oct. 27–28......	130	33
		115	29			131	33
		141	35	81....	A.H.M., 1905:		
71....	S.A.B., 1905:				Nov. 21–22......	160	40
	Jan. 7–10.......	[1] 210	53			131	33
		199	50	82....	H.C.K., 1905:		
		175	44		Nov. 24–25......	173	43
		144	36			179	45
72....	S.A.B., 1905:			83....	H.R.D., 1905:		
	Jan. 11.........	196	49		Dec. 5–6........	199	50
73....	S.A.B., 1905:					183	46
	Jan. 28–Feb. 1...	174½	44	85....	N.M.P., 1905:		
		182	46		Dec. 9–10.......	189	47
		203	51			198	50
		188	47	89....	D.W., 1906:		
		166	42		Jan. 10–11......	156	39
74....	S.A.B., 1905:					218	55
	Feb. 2–4........	190	48				
		201	50				
		192	48				
75....	S.A.B., 1905:						
	Mar. 4–10.......	176	44				
		175	44				
		232	58				
		224	56				
		185	46				
		191	48				
		160	40				

[1] No allowance has been made for 75 calories total output due to 10 minutes bicycle ride, 9 to 11 a. m. period.

From the above data the estimates given in table 234 were obtained. They are shown both in units and in calories. It must be understood, however, that in obtaining the figures in this table no attempt has been made to estimate the minor involuntary movements, hence the figures obtained give nearer the minimum than the maximum.

The figures recorded in column *b* of table 234 are admittedly but approximate estimations. Perhaps the most striking feature of the table is the fact that the differences between the experimental days when computed on the basis of calories are, relatively speaking, so small. The maximum difference observed in any fasting experiment is that of experiment No. 77, where there were 60 calories for the second day and 40 calories on the third, and yet the difference here recorded, 20 calories, is barely over 1 per cent of the average total heat production per day of this experiment. A comparison of the variations in muscular activity as expressed in calories given in this table with the total heat production on the succeeding days of each experiment shows that, while the fluctuations in the estimated energy of the external muscular activity are very small, they generally follow those appearing in the total heat production. That the differences in the heat production noted from day to day in the different fasts, however, can be directly caused by variations in visible external muscular activity is very completely disproven. A careful revision of the estimates given in this table has been made and it is certain that although there may be errors in the apportionment and the estimate of value of the activity, the error can certainly not be over 100 per cent and it is probably very much less. Assuming that an error of 100 per cent exists and that the error is always in the same direction, so as to increase the apparent differences on different days, the amounts even then are far too small to account for the absolute differences in the total heat production. It is clear, therefore, that while the variations in muscular activity are proportional to the variations in the total heat produced, some factor other than external muscular activity must account for the wide variations in the total heat production.

Relations of internal muscular activity to total heat production.—Aside from the external muscular activity, there is a considerable amount of muscular work which can be conveniently termed "internal" muscular work, typified perhaps by the work of respiration and circulation.

Estimates, which for the most part are based on the respiratory exchange, have been made of the energy required for circulation and respiration. Recently Loewy & v. Schrotter[160] have made an extensive study of these factors of internal work in man. From the results of their experiments they conclude that the total energy required for circulation is 3.6 per cent of the total energy transformation of a man at rest. The work of respiration is 2.4 times that of circulation, and the work of respiration and circulation combined amounts to about 13 per cent of the total energy output for the day.

[160] Zeit. f. exper. Path. u. Therapie (1905), 1, p. 197.

The arterial tension as well as pulse rate per minute are important factors in estimating the work of circulation, but unfortunately all attempts to measure accurately the blood pressure in these experiments failed.[164]

It is much to be regretted that in the longer experiments, which are of the greatest value for comparing the variations in the total heat production with the external and internal muscular activity, the records of pulse rate are defective. Furthermore, no records of the rate of respiration were obtained. A comparison, however, of the pulse rate and the total heat production is of interest. The subject of experiment No. 75, S. A. B., recorded the pulse with considerable regularity during the day. The first record was made in the morning, not far from $7^h\ 30^m$ a. m., and was undoubtedly influenced by the muscular activity attendant upon rising, weighing himself and his chair, bedding, etc. As an inspection of the data on page 170 shows, his pulse exhibits considerable irregularities from day to day during the period. By omitting this first observation and averaging the remainder during the fasting period, a rough approximation of the average pulse rate per day can be obtained.

A comparison (see p. 509) of this pulse rate with the total heat production shows a striking uniformity in fluctuations, and similar comparisons with other experiments show in nearly every instance a parallelism.

The pulse rates in the 2-day fasting experiments have been tabulated, together with the respiration rate and total heat production. Although the pneumograph method of obtaining pulse rate and respiration was, on the whole, extremely satisfactory, there were a number of days when the observations were more or less irregular and hence difficulties were experienced in obtaining a fair average pulse and respiration rate for each period. An examination of the detailed statistics for the experiments will show the data from which the averages recorded in table 235 were obtained.

Examination of the table shows that in general there is a very marked regularity in the results of pulse rate, respiration rate, and total heat production when they are compared. But there are a few striking anomalies. Perhaps the most noticeable is in experiment No. 81, where the pulse rate and respiration rate for the second period both increased on the second day, and yet the total heat production decreased nearly 80 calories.

In the decade in which experiments have been in progress in this laboratory, evidence has been accumulating to correlate the minor muscular activity with heat production, and the experience thus obtained has been utilized in estimating the visible muscular activity in terms of calories recorded in table 234. But it is obvious that careful measurements of pulse rate are of the greatest importance in obtaining an estimate of variations in the so-called internal muscular work. During "rest" experiments this factor evidently varies more than does the visible external muscular activity.

[164] Cathcart (Biochemische Zeitschrift (1907), 6, p. 109), finds that blood-pressure as well as pulse-rate decreases during inanition.

TABLE 285.—*Relation of pulse rate, respiration rate, and heat production in 2-day fasting metabolism experiments.*

Experiment number.	Subject and date.	Period.	Average pulse rate per minute.	Average respiration rate per minute.	Total heat production, calories.
79..	H. E. S., Oct. 13–14, 1905	7 a. m to 1 p. m.....	55	13	526
		1 p. m. to 7 p. m.....	61	18	472
		7 p. m. to 1 a. m.....	61	18	492
		1 a. m to 7 a. m.....	61	18	460
79..	H. E. S., Oct. 14–15.....	7 a. m. to 1 p. m.....	..	19	531
		1 p. m. to 7 p. m.....	73	19	525
		7 p. m. to 1 a. m.....	61	18	504
		1 a. m. to 7 a. m.....	..	18	486
80..	C. R. Y., Oct. 27–28.....	7 a. m. to 1 p. m.....	..	16	527
		1 p. m. to 7 p. m.....	56	16	449
		7 p. m to 1 a. m.....	57	15	493
		1 a. m. to 7 a. m.....	65	16	483
80..	C. R. Y., Oct. 28–29.....	7 a. m. to 1 p. m.....	78	16	592
		1 p. m. to 7 p. m.....	79	21	531
		7 p. m. to 1 a. m.....	77	17	486
		1 a. m. to 7 a. m.....	77	17	489
81..	A. H. M., Nov. 21–22....	7 a. m. to 1 p. m.....	46	15	485
		1 p. m. to 7 p. m.....	45	13	491
		7 p. m. to 1 a. m.....	43	14	395
		1 a. m. to 7 a. m.....	42	14	355
81..	A. H. M., Nov. 22–23....	7 a. m. to 1 p. m.....	57	18	540
		1 p. m. to 7 p. m.....	46	17	412
		7 p. m. to 1 a. m.....	49	17	427
		1 a. m. to 7 a. m.....	50	16	400
82..	H. C. K., Nov. 24–25....	7 a. m. to 1 p. m.....	66	23	642
		1 p. m. to 7 p. m.....	62	21	527
		7 p. m. to 1 a. m.....	59	20	584
		1 a. m. to 7 a. m.....	56	19	467
82..	H. C. K., Nov. 25–26....	7 a. m. to 1 p. m.....	68	24	709
		1 p. m. to 7 p. m.....	70	23	607
		7 p. m. to 1 a. m.....	72	23	634
		1 a. m. to 7 a. m.....	68	19	526
83..	H. R. D., Dec. 5–6......	7 a. m. to 1 p. m.....	76	20	565
		1 p. m. to 7 p. m.....	76	18	386
		7 p. m. to 1 a. m.....	74	18	536
		1 a. m. to 7 a. m.....	68	17	424
83..	H. R. D., Dec. 6–7......	7 a. m. to 1 p. m.....	85	18	585
		1 p. m. to 7 p. m.....	78	17	410
		7 p. m. to 1 a. m.....	71	18	478
		1 a. m. to 7 a. m.....	71	18	431
85..	N. M. P., Dec. 9–10......	7 a. m. to 1 p. m.....	62	12	594
		1 p. m. to 7 p. m	55	12	505
		7 p. m. to 1 a. m.....	58	12	534
		1 a m. to 7 a. m.....	62	12	474

TABLE 235.—*Relation of pulse rate, respiration rate, and heat production in 2-day fasting metabolism experiments*—Continued.

Experiment number.	Subject and date.	Period.	Average pulse rate per minute.	Average respiration rate per minute.	Total heat production, calories.
85..	N. M. P., Dec. 10–11, 1905	7 a. m. to 1 p. m.....	70	14	638
		1 p. m. to 7 p. m.....	63	14	559
		7 p. m. to 1 a. m.....	73	15	592
		1 a. m. to 7 a. m.....	76	15	513
89..	D. W., Jan. 10–11, 1906..	7 a. m. to 1 p. m.....	59	17	480
		1 p. m. to 7 p. m.....	63	19	606
		7 p. m. to 1 a. m.....	56	19	571
		1 a. m. to 7 a. m.....	50	16	492
89..	D. W., Jan. 11–12.......	7 a. m. to 1 p. m.....	59	16	530
		1 p. m. to 7 p. m.....	60	18	630
		7 p. m. to 1 a. m.....	63	20	626
		1 a. m. to 7 a. m.....	50	16	467

The differences in total heat production can in only very small part be accounted for by the actual differences in the work of circulation, assuming the accuracy of Loewy & v. Schrotter's[188] estimates of the relative proportion of the total energy output required for circulation, and consequently variations in pulse rate can be taken only as a general index of the fluctuations in the degree of the internal muscular activity including in all probability muscular tonus.

ENERGY OF THE URINE.

Fat and carbohydrate katabolized in the ordinary diet are, as a rule, wholly broken down to carbon dioxide and water, and the potential energy they originally contained is completely transformed into heat. A portion of the protein molecule, on the contrary, is not completely oxidized, and is excreted as urea and similar compounds in the urine. The energy of these compounds in the urine must be determined in any series of experiments in which the balance of energy is desired. In order to determine the potential energy of urine, it is necessary to burn the dry matter in a calorimetric bomb and measure the heat actually given off. The technique of the determination of the heat of combustion of urine has received special consideration in an earlier paragraph (see p. 16). The errors involved, in all probability render the determinations somewhat too low rather than too high, although the method used in these investigations has given the highest heat of combustion of any method with which we are familiar. In fasting urine we have reason to suppose not only that portions of the protein katabolized are excreted unoxi-

[188] Loc. cit.

dized but that there may be a more or less marked acidosis with an accompanying excretion of acids such as β oxybutyric acid resulting from the partial oxidation of fat. The total energy of the urine on each day of the fasting experiments is given in table 236.

TABLE 236.—*Total energy of urine excreted in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
		Cals.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
59...	B.F.D., Dec. 18–20, 1903......	91	106	111	...	...	...	...
68...	A.L.L., Apr. 27–28, 1904......	92	99	...	...	...	...	...
69...	A.L.L., Dec. 16–19, 1904......	92	112	120	110	...	...	...
71...	S.A.B., Jan. 7–10, 1905......	58	91	99	86	...	...	...
73...	S.A.B., Jan. 28–Feb. 1, 1905...	86	98	96	92	92	...	...
75...	S.A.B., Mar. 4–10, 1905......	97	136	138	146	147	146	139
77...	S.A.B., Apr. 8–11, 1505......	90	157	157	170	...	...	...
79...	A.E.S., Oct. 13–14, 1905......	72	116	...	...	...	...	...
80...	C.R.Y., Oct. 27–28, 1905......	75	97	...	...	...	...	...
81...	A.H.M., Nov. 21–22, 1905......	80	109	...	...	...	...	...
82...	H.C.K., Nov. 24–25, 1905......	88	122	...	...	...	...	...
83...	H.R.D., Dec. 5– 6, 1905......	116	151	...	...	...	...	...
85...	N.M.P., Dec. 9–10, 1905......	96	99	...	...	...	...	...
89...	D.W., Jan. 10–11, 1906......	93	114	...	...	...	...	...
	Average....................	88	115	120	121	120	146	139

The smallest amount was found on the first day of experiment No. 71, 58 calories, and the largest amount on the fourth day of experiment No. 77, 170 calories. The total energy is invariably somewhat greater on the second day than on the first. For all the experiments the average is 88 calories on the first day and 115 calories on the second. In the 5 experiments which lasted for 3 days or longer, the energy on the third day is a little greater than that on the second day, while in experiments Nos. 75 and 77, there is a marked increase of energy excreted in the urine on the fourth day. The excretion of energy in experiment No. 75 remains fairly constant after the first day. When it is considered that the energy liberated from the body in the form of heat in some of these experiments was as low as 1500 to 1600 calories, it can readily be seen that the energy of the urine may amount to nearly 10 per cent of the total energy and hence especial care should be taken in experiments during inanition to secure accurate measurements of this factor.

The assumption pointed out on page 395 that non-nitrogenous material of high carbon content is excreted in the urine during fasting receives substantiation from the figures for the heat of combustion, for it is seen that the large carbon excretion in the urine of experiments Nos. 75 and 77 is paralleled by a large amount of energy. The difficulties attending the direct determination of the energy of urine have led to the attempt to secure a factor for

computation from the amounts of nitrogen and carbon known to be contained in the urine. In these experiments not only was the amount of energy determined but also the nitrogen and carbon and organic matter, so that we have the means for determining the ratio of the heat of combustion to the nitrogen, carbon, and organic matter. These ratios have been calculated and are given in the following table. The results are expressed in terms of the number of calories of energy which accompany 1 gram of nitrogen, carbon, and organic matter, respectively.

Thus, on the first day of experiment No. 77, for every gram of nitrogen in the urine, there was found to be 10.216 calories of energy. For every gram of carbon there were on this day 11.292 calories, and for every gram of organic matter, 3.184 calories. An inspection of these ratios shows that the ratio of energy to nitrogen may vary considerably. The lowest ratio observed is on the third day of experiment No. 59, 7.490, and the highest is that observed on the fourth day of experiment No. 77, 14.847. The average ratio is not far from 9. In the nitrogen metabolism experiments, the heat of combustion of the urine was determined on 6 days. The respective ratios of the heat of combustion to nitrogen were 8.8, 11.0, 9.6, 9.3, 8.3, and 9.8, respectively.

The ratio of energy to carbon is much more nearly constant, the lowest ratio (9.436) observed being on the first day of experiment No. 68 and the highest on the first day of experiment No. 85 (12.468). Here the differences are very much less than in the case of the energy-nitrogen ratio and it is fair to assume that in experiments of this character for every gram of carbon in the urine there are not far from 11.5 calories of energy.

The determination of carbon in the urine is, however, not much less troublesome than the determination of energy and this ratio is, therefore, not of especial value, although it is unusually constant. Since the carbon is in large measure proportional to the total organic matter, the ratio of heat of combustion to organic matter is of interest since the organic matter can be determined with little difficulty. These ratios have been computed and are recorded in table 237. They show that for every gram of organic matter there may be energy corresponding to from 2.264 to 3.857 calories, but in a large majority of instances, the ratio is not far from 3.2. While by no means as constant as the energy-carbon ratio, the energy-organic matter ratio is much more satisfactory than that based upon the determination of nitrogen. In practically all of the experiments here reported, the use of the factor 3.2 as the ratio of energy to organic mattter would have given results which would not have seriously affected the final computations. It is of especial importance, however, to note that in these determinations the total transformations of energy were extremely small and consequently in ordinary metabolism experiments where the energy transformations are larger the total energy in the urine may be computed from the organic matter and the results be well within the limits of error.

TABLE 237.—*Ratio of heat of combustion to nitrogen, carbon, and organic matter of urine in metabolism experiments without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
59...	B.F.D., Dec. 18–20, 1903:							
	Nitrogen.........	7.696	7.512	7.490	....	....	....	....
	Carbon...........	10.448	10.192	10.165	....	....	....	....
	Organic matter...	2.312	2.275	2.265	....	....	....	....
68...	A.L.L., Apr. 27–28, 1904:							
	Nitrogen.........	7.504	7.598	....	....	....	....	....
	Carbon...........	9.436	9.547	....	....	....	....	....
	Organic matter...	2.675	2.712	....	....	....	....	....
69...	A.L.L., Dec. 16–19, 1904:							
	Nitrogen.........	9.118	7.854	7.979	8.481	....	....	....
	Carbon...........	11.071	11.234	11.572	11.677	....	....	....
	Organic matter...	3.128	2.902	2.932	3.038	....	....	....
71...	S.A.B., Jan. 7–10, 1905:							
	Nitrogen.........	9.932	8.243	7.557	8.007	....	....	....
	Carbon...........	11.111	10.977	11.458	11.125	....	....	....
	Organic matter...	3.247	2.942	2.823	2.810	....	....	....
73...	S.A.B., Jan. 28–Feb. 1, 1905:							
	Nitrogen.........	8.358	8.187	8.319	8.855	9.218	....	....
	Carbon...........	11.513	11.793	12.106	12.010	11.660	....	....
	Organic matter...	3.014	3.030	3.078	3.102	3.078	....	....
75...	S.A.B., Mar. 4–10, 1905:							
	Nitrogen.........	7.925	10.924	10.599	12.554	13.523	13.594	13.722
	Carbon...........	11.916	11.826	12.421	11.967	11.621	12.146	12.257
	Organic matter...	2.977	3.553	3.550	3.744	3.830	3.857	3.644
77...	S.A.B., Apr. 8–11, 1905:							
	Nitrogen.........	10.216	14.564	14.299	14.847	....	....	....
	Carbon...........	11.292	11.263	11.460	11.669	....	....	....
	Organic matter...	3.184	3.679	3.613	3.740	....	....	....
79...	H.E.S., Oct. 13–14, 1905:							
	Nitrogen.........	8.878	8.084	....	....	....	....	....
	Carbon...........	11.483	11.350	....	....	....	....	....
	Organic matter...	3.216	3.055	....	....	....	....	....
80...	C.R.Y., Oct. 27–28, 1905:							
	Nitrogen.........	9.640	9.749	....	....	....	....	....
	Carbon...........	10.549	10.754	....	....	....	....	....
	Organic matter...	3.301	3.225	....	....	....	....	....
81...	A.H.M., Nov. 21–22, 1905:							
	Nitrogen.........	8.782	8.352	....	....	....	....	....
	Carbon...........	10.638	11.498	....	....	....	....	....
	Organic matter...	3.062	2.960	....	....	....	....	....
82...	H.C.K., Nov. 24–25, 1905:							
	Nitrogen.........	9.382	8.496	....	....	....	....	....
	Carbon...........	11.414	11.328	....	....	....	....	....
	Organic matter...	3.205	3.161	....	....	....	....	....
83...	H.R.D., Dec. 5–6, 1905:							
	Nitrogen.........	8.755	11.160	....	....	....	....	....
	Carbon...........	11.885	11.815	....	....	....	....	....
	Organic matter...	3.127	3.441	....	....	....	....	....
85...	N.M.P., Dec. 9–10, 1905:							
	Nitrogen.........	8.443	8.722	....	....	....	....	....
	Carbon...........	12.468	12.044	....	....	....	....	....
	Organic matter...	3.066	3.154	....	....	....	....	....
89...	D.W., Jan. 10–11, 1906:							
	Nitrogen.........	9.309	7.884	....	....	....	....	....
	Carbon...........	11.098	11.550	....	....	....	....	....
	Organic matter...	2.951	2.855	....	....	....	....	....

Data were at hand for the computation of the ratio of the heat of combustion of urine to organic matter in the food experiments Nos. 70, 72, 74, and 76 and the results are presented in table 238.

TABLE 238.—*Relation of heat of combustion to organic matter of urine in metabolism experiments with food.*

Experiment number.	Subject and date.	(a) Total organic matter of urine.	(b) Heat of combustion of urine.	(c) Ratio of heat of combustion to organic matter (b÷a).
70	A.L.L.:	*Grams.*	*Calories.*	
	Dec. 20–21, 1904	35.59	103	2.894
	Dec. 21–22, 1904	29.30	82	2.799
	Dec. 22–23, 1904	29.61	91	3.073
72	S.A.B.:			
	Jan. 11–12, 1905	29.48	84	2.849
74	S.A.B.:			
	Feb. 2– 3, 1905	29.47	88	2.986
	Feb. 3– 4, 1905	24.06	68	2.826
	Feb. 4– 5, 1905	20.70	61	2.947
76	S.A.B.:			
	Mar. 11–12, 1905	38.88	125	3.215
	Mar. 12–13, 1905	21.41	66	3.083
	Mar. 13–14, 1905	23.40	69	2.949

So far as experiments Nos. 70, 72, and 74 are concerned the ratios are not unlike those obtained in the fasting experiments preceding each, but there is a marked decrease in the ratio between the seventh day of experiment No. 75 and the 3 days of experiment No. 76. The ratio gradually decreases on the 3 successive days of this experiment, ultimately reaching a value not far from that observed in the 2 earlier food experiments with this subject.

No data regarding the ratio of heat of combustion to organic matter were secured in the nitrogen metabolism experiments made with this subject. Although the energy was determined in a few instances, no determinations of the organic matter were made.

The factor proposed, then, for comparing the total organic matter with the energy, namely, 3.2, represents with reasonable accuracy the ratio of energy to organic matter, found not only during fasting but also in the food experiments. Since the determination of organic matter is relatively simple, this factor should be of value in computing the energy eliminated in the urine where the actual determination of the heat of combustion can not be made.

The only other ratios of the heat of combustion to carbon and organic matter in experiments on fasting man with which we are familiar are those obtained in connection with experiments made in this laboratory and reported elsewhere.[199] The ratios of the heat of combustion to nitrogen, carbon, and organic

[199] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

matter of urine determined in a 1-day fasting experiment (No. 36) were not published in that report. They were found to be 8.39, 11.12, and 2.59, respectively. The ratio of heat of combustion to nitrogen has been computed for the other fasting experiments published simultaneously with experiment No. 36, although the data were lacking for computing the ratios of heat of combustion to carbon and organic matter. The ratio Cal.: N in experiments Nos. 39, 42, and the 2 days of experiment No. 51 were 8.19, 7.66, 8.19, and 7.08 respectively.

Ratios of heat of combustion to nitrogen as wide as those obtained in some of these fasting experiments have rarely been observed.

A disturbance of the proteid metabolism accompanied by unusually large Cal.: N ratios during residence in high altitudes was observed and reported by Loewy,[187] who was able to isolate a considerable amount of amino bodies from the urine. Indeed, there seemed to be a distinct relation between the quantities of amino bodies and the height at which the subject of the experiments dwelt. While we have but little reason to expect an excessive elimination of amino bodies in the urine of fasting men, the high ratio of heat of combustion to nitrogen may well be explained by the formation of acids such as has been pointed out in the discussion on the carbon and energy content of the urine.

ENERGY OF KATABOLIZED BODY MATERIAL.

In the course of katabolism during inanition, varying quantities of protein, fat, and carbohydrate are disintegrated. The amounts thus katabolized have been discussed in the several sections. Since these compounds are capable of supplying widely varying quantities of energy to the body, it is of interest to note the proportions of the total energy liberated in the body as a result of the katabolism of the three compounds.

Proportion of energy derived from different sources.—The proportions of the energy supplied by the protein, fat, and glycogen have been computed and recorded in table 239. In this discussion the net energy of the protein, i. e., the energy of the protein less that of the unoxidized material of the urine, alone is considered. One possible source of error is present in this method inasmuch as it is here assumed that the unoxidized material of the urine is derived wholly from protein. Under normal conditions this is probably the case, but with the possibilities of an acidosis as a result of partial oxidation and cleavage of fat, it is obviously erroneous to deduct from the energy of the protein katabolized, the energy of the urine in case a portion of the energy of the urine has been derived from fat. The effect of this assumption is to decrease the proportion of the total energy derived from the protein and to increase the proportion actually derived from fat. Unfortunately no data are at hand to show the exact magnitude of the error thus involved.

[187] Deutsch. med. Wochenschrift (1905), 48, p. 1918.

TABLE 239.—*Proportion of energy derived from different sources in metabolism experiments with and without food.*

Experiment number.	Subject and date.	From net energy of protein.	From fat.	From glycogen.
	Experiments without food.			
59..	B.F.D., 1903:	*P. ct.*	*P. ct.*	*P. ct.*
	Dec. 18–19....	14.6	67.8	17.6
	Dec. 19–20....	17.6	70.6	11.8
	Dec. 20–21....	18.1	81.1	0.8
68..	A.L.L., 1904:			
	Apr. 27–28....	14.9	63.5	21.6
	Apr. 28–29....	15.8	70.3	13.9
69..	A.L.L., 1904:			
	Dec. 16–17....	12.7	65.3	22.0
	Dec. 17–18....	17.1	76.8	6.1
	Dec. 18–19....	18.9	74.5	6.6
	Dec. 19–20....	16.4	80.4	3.2
71..	S.A.B., 1905:			
	Jan. 7– 8....	7.0	55.2	37.8
	Jan. 8– 9....	15.2	78.1	6.7
	Jan. 9–10....	19.2	75.7	5.1
	Jan. 10–11....	16.8	76.8	6.4
73..	S.A.B., 1905:			
	Jan. 28–29....	14.2	55.1	30.7
	Jan. 29–30....	16.8	79.0	4.2
	Jan. 30–31....	16.6	81.7	1.7
	Jan. 31–Feb. 1.	15.5	79.1	5.4
	Feb. 1– 2....	12.5	87.5	....
75..	S.A.B., 1905:			
	Mar. 4– 5....	17.7	67.1	15.2
	Mar. 5– 6....	16.0	78.6	5.4
	Mar. 6– 7....	17.0	81.7	1.3
	Mar. 7– 8....	14.3	79.6	6.1
	Mar. 8– 9....	13.5	84.4	2.1
	Mar. 9–10....	14.1	80.0	5.9
	Mar. 10–11....	13.2	81.8	5.0
77..	S.A.B., 1905:			
	Apr. 8– 9....	11.1	68.3	20.6
	Apr. 9–10....	10.9	85.9	3.2
	Apr. 10–11....	12.1	74.0	13.9
	Apr. 11–12....	12.3	80.8	6.9
79..	H.E.S., 1905:			
	Oct. 13–14....	10.4	64.5	25.1
	Oct. 14–15....	18.1	73.8	8.1

Experiment number.	Subject and date.	From net energy of protein.	From fat.	From glycogen.
	Experiments without food.			
80..	C.R.Y., 1905:	*P. ct.*	*P. ct.*	*P. ct.*
	Oct. 27–28....	9.6	68.5	21.9
	Oct. 28–29....	11.3	85.3	3.4
81..	A.H.M., 1905:			
	Nov. 21–22....	13.1	80.1	6.8
	Nov. 22–23....	12.8	87.2	....
82..	H.C.K., 1905:			
	Nov. 24–25....	10.2	59.1	30.7
	Nov. 25–26....	14.6	77.9	7.5
83..	H.R.D., 1905:			
	Dec. 5–6......	17.0	76.0	7.0
	Dec. 6–7......	16.6	74.0	9.4
85..	N.M.P., 1905:			
	Dec. 9–10....	13.7	57.4	28.9
	Dec. 10–11....	12.6	70.5	16.9
89..	D.W., 1906:			
	Jan. 10–11....	11.2	57.2	31.6
	Jan. 11–12....	16.4	76.3	7.3
	Experiments with food.			
70..	A.L.L., 1904:			
	Dec. 20–21....	16.2	72.4	11.4
	Dec. 21–22....	11.2	82.1	6.7
	Dec. 22–23....	10.2	72.8	17.0
72..	S.A.B., 1905:			
	Jan. 11–12....	16.0	81.5	2.5
74..	S.A.B., 1905:			
	Feb. 2–3......	16.1	77.1	6.8
	Feb. 3–4......	12.8	64.9	22.3
	Feb. 4–5......	10.1	71.0	18.9
76..	S.A.B., 1905:			
	Mar. 11–12....	12.4	74.3	13.3
	Mar. 12–13....	10.4	57.2	32.4
	Mar. 13–14....	11.2	36.5	52.3

For purposes of comparison, the proportions of energy from the protein, fat, and glycogen in the experiments with food are included in the table.

From 10 to 15 per cent of the total energy produced is derived from protein. The smallest percentage is on the first day of experiment No. 71, where but 7

per cent of the total energy was derived from protein. The largest proportion is on the third day of experiment No. 71, namely, 19.2 per cent. In the food experiments the proportions derived from protein are not materially different on the whole from those observed during fasting.

An examination of the proportions of energy derived from fat shows considerable variations, which are especially noticeable on the first days of the longer fasting experiments. The apportionment of the carbon other than that of protein between the fat and glycogen would lead to the supposition that as the quantity of katabolized glycogen decreased, the amount of fat would be increased, and this is actually what is found in comparing the amounts of these two materials katabolized. Similar fluctuations in the energy derived from the two compounds are also observed. No regularity appears in the proportion of the energy resulting from fat. It is generally greater than 75 per cent, but in fasting experiments may be as small as 55 per cent. In one instance, namely, on the last day of food experiment No. 76, it fell to 36.5 per cent. The highest proportion was found on the last day of experiment No. 73.

Since a much smaller proportion of the total energy results from glycogen rather than from fat katabolism, the fluctuations in the proportions of the energy supplied by the glycogen are very considerable, and it is difficult to obtain any general average for the amount of energy furnished by this compound. In two instances there was apparently an absorption of energy due to the formation and storage of glycogen,[169] namely, on the last day of experiment No. 73 and the second day of experiment No. 81. This apparent storage or absorption of energy in the form of glycogen could only be derived from body fat or protein, and hence the absorption of energy is apparent and not real. The largest proportion of energy supplied by glycogen on any one day in the fasting experiments was 37.8 per cent. On the last day of food experiment No. 76, a maximum of 52.3 per cent was reached.

COMPARISON OF PRODUCTS OF KATABOLISM AND HEAT PRODUCTION.

It has commonly been assumed that heat production and katabolism are interdependent and the older methods of computing the heat production were based on this assumption. Therefore, experiments in which all the grosser factors of katabolism have been studied present unusual opportunity for an examination of the regularity of the course of the heat production compared to that of the general katabolism. Such a comparison may be made in several ways. The relations between the grosser factors, oxygen consumption, carbon dioxide and water elimination, and heat production are first studied, and later the numerous other products of katabolism, especially those appearing in the urine, are compared.

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[169] For errors affecting the storage of glycogen see discussion of ratios of carbon dioxide and oxygen to heat, p. 514.

TABLE 240.—*Proportion of oxygen consumed and of carbon dioxide and water eliminated and heat produced during different periods of the day in metabolism experiments without food.*

Period.	Exp. No. 59, subject B.F.D., 3 days.				Exp. No. 68, subject A.L.L., 2 days.			
	Oxygen.	Carbon dioxide.	Water.	Heat.	Oxygen.	Carbon dioxide.	Water.	Heat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7 a.m. to 10 a.m.	15.54	14.78	13.22	15.04	15.63	15.21	13.68	13.77
10 a.m. 1 p.m.	12.33	13.05	12.95	13.30	12.50	13.07	12.46	13.36
Total, 6 hours	27.87	27.83	26.17	28.34	28.13	28.28	26.14	27.13
1 p.m. to 4 p.m.	13.04	13.00	12.30	12.72	12.94	13.03	12.50	13.14
4 p.m. 7 p.m.	13.47	13.70	12.82	13.74	13.72	13.55	12.74	13.58
Total, 6 hours	26.51	26.70	25.12	26.46	26.66	26.58	25.24	26.72
Total, 12 hours	54.38	54.53	51.29	54.80	54.79	54.86	51.38	53.85
7 p.m. to 10 p.m.	13.63	13.07	12.35	13.15	12.98	12.95	12.08	12.97
10 p.m. 1 a.m.	10.97	11.13	11.93	10.51	11.44	11.78	12.35	12.15
Total, 6 hours	24.60	24.20	24.28	23.66	24.42	24.73	24.43	25.12
1 a.m. to 4 a.m.	10.76	10.33	12.13	10.03	10.50	10.03	12.22	10.43
4 a.m. 7 a.m.	10.26	10.94	12.30	11.51	10.29	10.38	11.97	10.60
Total, 6 hours	21.02	21.27	24.43	21.54	20.79	20.41	24.19	21.03
Total, 12 hours	45.62	45.47	48.71	45.20	45.21	45.14	48.62	46.15
	Exp. No. 69, subject A.L.L., 4 days.				Exp. No. 71, subject S.A.B., 4 days.			
7 a.m. to 9 a.m.	10.82	11.04	9.85	10.16	12.56	12.18	10.73	11.21
9 a.m. 11 a.m.	7.87	8.08	7.96	7.73	10.37	10.85	9.73	10.72
11 a.m. 1 p.m.	8.24	8.22	8.11	7.82	8.38	9.07	8.49	9.51
Total, 6 hours	26.93	27.34	25.92	25.71	31.31	32.10	28.95	31.44
1 p.m. to 3 p.m.	9.30	9.06	7.94	9.85	9.59	9.01	8.62	8.81
3 p.m. 5 p.m.	8.63	8.79	8.08	8.98	8.03	8.21	8.50	7.66
5 p.m. 7 p.m.	8.63	8.98	8.07	9.45	8.63	8.50	8.93	9.77
Total, 6 hours	26.56	26.83	24.09	28.28	26.25	25.72	26.05	26.24
Total, 12 hours	53.49	54.17	50.01	53.99	57.56	57.82	55.00	57.68
7 p.m. to 9 p.m.	9.17	8.74	7.99	8.51	9.25	8.85	8.54	8.08
9 p.m. 11 p.m.	8.07	8.33	7.59	8.25	7.44	7.41	7.54	5.60
11 p.m. 1 a.m.	7.54	7.65	8.43	8.12	6.34	6.64	7.62	8.28
Total, 6 hours	24.78	24.72	24.01	24.88	23.03	22.90	23.70	21.96
1 a.m. to 3 a.m.	7.32	6.86	8.78	6.98	6.71	6.40	7.52	6.36
3 a.m. 5 a.m.	7.25	7.13	9.21	7.01	6.65	6.41	6.49	7.09
5 a.m. 7 a.m.	7.16	7.12	7.99	7.14	6.05	6.47	7.29	6.91
Total, 6 hours	21.73	21.11	25.98	21.13	19.41	19.28	21.30	20.36
Total, 12 hours	46.51	45.83	49.99	46.01	42.44	42.18	45.00	42.32

TABLE 240.—*Proportion of oxygen consumed and of carbon dioxide and water eliminated and heat produced during different periods of the day in metabolism experiments without food*—Continued.

Period.	Exp. No. 73, subject S.A.B., 5 days.				Exp. No. 75, subject S.A.B., 7 days.			
	Oxygen.	Carbon dioxide.	Water.	Heat.	Oxygen.	Carbon dioxide.	Water.	Heat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7 a.m. to 9 a.m.	11.51	11.24	9.70	10.14	10.90	10.42	10.29	10.60
9 a.m. 11 a.m.	9.70	9.88	9.44	10.05	8.83	9.44	8.69	10.01
11 a.m. 1 p.m.	9.06	9.21	8.65	9.29	8.74	8.98	8.26	9.00
Total, 6 hours..	30.27	30.33	27.79	29.48	28.47	28.84	27.24	29.61
1 p.m. to 3 p.m.	8.57	8.91	8.38	8.97	8.72	8.90	8.40	8.94
3 p.m. 5 p.m.	8.77	6.84	8.09	8.48	9.08	8.45	7.82	8.50
5 p.m. 7 p.m.	9.04	9.21	8.51	9.62	9.00	9.07	7.93	9.32
Total, 6 hours..	26.38	26.76	24.98	27.07	26.80	26.42	24.15	26.76
Total, 12 hours.	56.65	57.09	52.77	56.55	55.27	55.26	51.39	56.37
7 p.m. to 9 p.m.	8.37	8.40	8.49	8.60	8.08	8.42	7.91	8.10
9 p.m. 11 p.m.	8.18	8.01	8.09	7.85	8.90	8.52	8.39	7.83
11 p.m. 1 a.m.	5.99	6.74	7.82	5.93	6.10	6.79	7.99	6.01
Total, 6 hours..	22.54	23.15	24.40	22.38	23.08	23.73	24.29	21.94
1 a.m. to 3 a.m.	7.03	6.32	7.70	6.11	6.50	6.51	8.07	6.45
3 a.m. 5 a.m.	6.99	6.89	7.63	7.66	7.71	7.06	8.20	7.79
5 a.m. 7 a.m.	6.79	6.55	7.50	7.30	7.44	7.44	8.05	7.44
Total, 6 hours..	20.81	19.76	22.83	21.07	21.65	21.01	24.32	21.69
Total, 12 hours.	43.35	42.91	47.23	43.45	44.73	44.74	48.61	43.63
	Exp. No. 77, subject S.A.B., 4 days.				Experiments Nos. 79-83, 85, and 90.			
7 a.m. to 9 a.m.	11.17	10.86	10.60	9.78	11.32	10.93	9.29	10.69
9 a.m. 11 a.m.	7.92	8.29	8.14	8.66	7.91	8.81	8.33	8.26
11 a.m. 1 p.m.	7.58	7.79	8.06	7.96	8.69	8.82	8.43	8.63
Total, 6 hours..	26.67	26.94	26.80	26.40	27.92	28.56	26.05	27.58
1 p.m. to 3 p.m.	8.09	8.70	8.36	8.56	8.24	8.36	8.13	8.46
3 p.m. 5 p.m.	8.91	8.56	7.76	9.47	7.95	7.95	8.00	7.58
5 p.m. 7 p.m.	8.58	8.12	8.31	8.53	8.51	8.12	8.47	8.55
Total, 6 hours..	25.58	25.38	24.43	26.56	24.70	24.43	24.60	24.59
Total, 12 hours.	52.25	52.32	51.23	52.96	52.62	52.99	50.65	52.17
7 p.m. to 9 p.m.	8.18	8.54	8.25	7.78	9.28	8.97	8.56	9.06
9 p.m. 11 p.m.	9.85	9.37	8.35	8.05	8.44	8.29	8.16	8.34
11 p.m. 1 a.m.	6.14	7.00	7.93	6.88	7.47	7.80	8.18	8.10
Total, 6 hours..	24.17	24.91	24.53	22.71	25.19	25.06	24.90	25.41
1 a.m. to 3 a.m.	7.68	7.22	8.07	7.16	7.21	7.03	8.13	7.21
3 a.m. 5 a.m.	7.81	7.78	8.02	8.68	7.35	7.28	7.94	7.27
5 a.m. 7 a.m.	8.09	7.77	8.15	8.49	7.63	7.64	8.38	7.94
Total, 6 hours..	23.58	22.77	24.24	24.33	22.19	21.95	24.45	22.42
Total, 12 hours.	47.75	47.86	48.77	47.04	47.38	47.01	49.35	47.83

Proportion of oxygen consumed, carbon dioxide and water eliminated, and heat produced during different periods.—The variations in the amounts of the four factors—oxygen, carbon dioxide, water, and heat—which occur during the different periods of the day are recorded in terms of per cents in table 240.

A certain parallelism appears in the proportions of these four factors; thus, the largest katabolic activity occurs, as a rule, during the first period of the day when more oxygen is consumed and carbon dioxide and water given off and heat produced than during any other period of the day. A close examination of the figures shows that in the 2-hour periods during the night from 1 to 7 a. m., the results from period to period are on the whole more nearly constant than during those of any other 6 hours. As has been shown in the foregoing discussion, the influence of external muscular activity is comparatively unimportant in its effect on the total heat production of a fasting man at rest. The results further show that although fluctuations in the pulse rate (assumed to be due to changes in the work of circulation) do not account for the marked differences in the accompanying heat production, nevertheless the pulse rate has been found to be a remarkably good index of the rise or fall in the amount of heat produced. The external muscular activity as well as the pulse rate is usually lowest during the period from 1 to 7 a. m.

During periods of sleep major muscular movements were not impossible, but it is probable that in general the subjects were in about the same degree of muscular activity in all the experiments. It is quite probable that extraneous muscular exertion can be neglected, although undoubtedly on certain nights, when the subjects reported a poor night's sleep or the physical assistant recorded unusual muscular activity, the external muscular activity did have an influence on the total katabolism. It is of especial interest to study the four important factors during this night period. For purposes of comparison, the amount of oxygen consumed, carbon dioxide and water given off, and heat produced per minute, are computed from 1 to 7 a. m. in all the experiments with and without food. These results are given in table 241.

The striking feature of these comparisons is the fact that in the longer experiments, except No. 77, which was abnormal in this and other respects, during the night period when the muscular activity is at the minimum, there is a progressive diminution in the total katabolism as indicated by the consumption of oxygen, the elimination of carbon dioxide and water-vapor, and the production of heat. This observation is also true when the computations are made on the basis of per kilo of body-weight or per square meter of body surface.

TABLE 241.—*Volume of oxygen consumed and amounts of carbon dioxide and water eliminated and heat produced per minute from 1 a. m. to 7 a. m. in metabolism experiments with and without food.*

Experiment number.	Subject and date.	Oxygen consumed.		Carbon dioxide eliminated.		Water eliminated.		Heat production.	
		Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.
		c.c.	*c.c.*	*c.c.*	*c.c.*	*Gram.*	*Gram.*	*Calorie.*	*Calorie.*
59...	B. F. D., 1903:								
	Dec. 18–19	3.721	122.8	2.894	95.50	.0096	.3161	.0176	.5814
	Dec. 19–20.....	4.071	133.7	3.067	100.71	.0098	.3211	.0190	.6242
	Dec. 20–21.....	3.966	129.8	3.031	99.23	.0101	.3315	.0202	.6616
68...	A. L. L., 1904:								
	Apr. 27–28....	3.523	119.1	2.733	92.40	.0066	.2223	.0167	.5640
	Apr. 28–29....	3.738	125.6	2.819	94.69	.0076	.2553	.0192	.6453
69...	A. L. L., 1904:								
	Dec. 16–17....	3.616	123.0	2.737	93.12	.0073	.2486	.0173	.5897
	Dec. 17–18....	3.691	125.1	2.630	89.15	.0098	.3308	.0174	.5905
	Dec. 18–19....	3.499	118.2	2.598	87.75	.0076	.2561	.0147	.4957
	Dec. 19–20....	3.507	118.1	2.555	86.06	.0069	.2307	.0163	.5489
70...	A. L. L., 1904:								
	Dec. 20–21....	3.328	111.9	2.629	88.38	.0088	.2974	.0165	.5545
	Dec. 21–22....	3.242	108.9	2.654	89.15	.0099	.3342	.0177	.5957
	Dec. 22–23....	4.264	143.2	3.412	114.58	.0111	.3719	.0221	.7423
71...	S. A. B., 1905:								
	Jan. 7– 8....	3.952	124.0	2.946	92.42	.0065	.2027	.0172	.5395
	Jan. 8– 9....	3.658	114.3	2.956	92.34	.0071	.2211	.0190	.5949
	Jan. 9–10....	3.434	106.9	2.608	81.20	.0065	.2014	.0178	.5556
	Jan. 10–11....	3.433	106.5	2.561	79.40	.0061	.1880	.0175	.5428
72...	S. A. B., 1905:								
	Jan. 11–12....	3.324	102.8	2.593	80.17	.0064	.1967	.0171	.5288
73...	S. A. B., 1905:								
	Jan. 28–29....	3.837	121.0	2.944	92.87	.0074	.2344	.0189	.5961
	Jan. 29–30....	3.720	116.7	2.734	85.75	.0068	.2144	.0181	.5662
	Jan. 30–31....	3.657	114.2	2.520	78.68	.0066	.2047	.0171	.5351
	Jan. 31–Feb. 1.	3.642	113.2	2.551	79.30	.0065	.2022	.0175	.5454
	Feb. 1– 2....	3.727	115.3	2.540	78.59	.0065	.2008	.0169	.5215
74...	S. A. B., 1905:								
	Feb. 2– 3....	3.330	102.9	2.562	79.19	.0065	.2007	.0162	.5018
	Feb. 3– 4....	3.462	107.2	2.670	82.68	.0063	.1943	.0156	.4826
	Feb. 4– 5....	3.703	114.9	2.691	83.47	.0061	.1881	.0160	.4952
75...	S. A. B., 1905:								
	Mar. 4– 5....	3.779	119.9	2.931	92.94	.0074	.2352	.0187	.5919
	Mar. 5– 6....	4.267	135.0	2.866	90.71	.0073	.2295	.0179	.5660
	Mar. 6– 7....	3.822	120.4	2.726	85.88	.0077	.2417	.0183	.5766
	Mar. 7– 8....	3.460	108.5	2.606	81.73	.0068	.2134	.0184	.5758
	Mar. 8– 9....	3.688	115.3	2.532	79.14	.0069	.2157	.0174	.5435
	Mar. 9–10....	3.342	104.2	2.552	79.57	.0065	.2041	.0164	.5109
	Mar. 10–11....	3.461	107.6	2.548	79.22	.0066	.2062	.0167	.5199

TABLE 241.—*Volume of oxygen consumed and amounts of carbon dioxide and water eliminated and heat produced per minute from 1 a. m. to 7 a. m. in metabolism experiments with and without food*—Continued.

Experiment number.	Subject and date.	Oxygen consumed.		Carbon dioxide eliminated.		Water eliminated.		Heat production.	
		Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.	Per kilogram of body-weight.	Per square meter of body surface.
		c.c.	*c.c.*	*c.c.*	*c.c.*	*Gram.*	*Gram.*	*Calorie.*	*Calorie.*
76...	S. A. B., 1905:								
	Mar. 11–12....	3.449	107.0	2.685	83.30	.0070	.2186	.0173	.5372
	Mar. 12–13....	3.243	100.6	2.691	83.50	.0067	.2085	.0163	.5065
	Mar. 13–14....	3.236	100.7	2.943	91.56	.0069	.2144	.0168	.5211
77...	S. A. B., 1905:								
	Apr. 8– 9....	3.975	127.3	3.125	100.06	.0073	.2330	.0194	.6216
	Apr. 9–10....	4.091	130.3	2.994	95.35	.0069	.2202	.0206	.6566
	Apr. 10–11....	4.302	135.9	3.064	96.81	.0071	.2241	.0222	.7008
	Apr. 11–12....	4.511	141.6	3.131	98.28	.0076	.2379	.0219	.6862
79...	H. E. S., 1905:								
	Oct. 13–14....	4.617	144.0	3.562	111.07	.0086	.2683	.0226	.7045
	Oct. 14–15....	4.736	146.6	3.695	114.40	.0084	.2611	.0244	.7547
80...	C. R. Y., 1905:								
	Oct. 27–28....	4.056	134.8	3.051	101.37	.0117	.3874	.0196	.6517
	Oct. 28–29....	4.404	145.0	3.328	109.60	.0110	.3633	.2004	.6722
81...	A. H. M., 1905:								
	Nov. 21–22....	3.575	114.6	2.656	85.17	.0063	.2026	.0160	.5141
	Nov. 22–23....	3.753	119.6	2.695	85.88	.0077	.2446	.0184	.5868
82...	H. C. K., 1905:								
	Nov. 24–25....	3.552	119.5	2.923	98.40	.0071	.2377	.0182	.6133
	Nov. 25–26....	4.299	144.0	3.273	109.61	.0081	.2715	.0208	.6977
83...	H. R. D., 1905:								
	Dec. 5– 6....	4.345	134.5	3.327	102.97	.0086	.2653	.0213	.6592
	Dec. 6– 7....	4.628	142.7	3.295	101.60	.0078	.2394	.0219	.6764
85...	N. M. P., 1905:								
	Dec. 9–10....	4.001	131.9	3.083	101.63	.0076	.2489	.0197	.6498
	Dec. 10–11....	4.410	144.5	3.420	112.08	.0090	.2964	.0217	.7118
89...	D. W., 1906:								
	Jan. 10–11....	3.690	128.2	2.871	99.76	.0071	.2460	.0175	.6064
	Jan. 11–12....	3.430	118.5	2.701	93.36	.0068	.2345	.0168	.5821

The minimum oxygen consumption per kilo of body-weight per minute occurs on the third day of the food experiment No. 76. The elimination of carbon dioxide is lowest on the third day of the fasting experiment No. 73, while the heat production is lowest on the third day of fasting experiment No. 69. The high heat production on the last night of experiment No. 70 is unquestionably associated with a febrile temperature observed on this day. In

what manner this high heat production is associated with fever,[109] the experiments do not show, since the pulse rate and respiration rate are not known. For the food experiments with S. A. B. there was no increase in the heat production in experiment No. 72 over the last day of experiment No. 71. Similarly in experiment No. 74, the heat production during the night was even less than during the fasting period of experiment No. 73. Experiment No. 76 showed, on the average, a slight increase over the heat production of the last days of experiment No. 75. It is reasonable to suppose, therefore, that any variation in the heat production during the ingestion of food is not prolonged into the night period from 1 to 7 a. m. Unpublished experiments made in this laboratory indicate that the extra heat production following the ingestion of food is in large part dissipated shortly after the food is taken, the normal resting metabolism without food being reached after a few hours.

With the subject S. A. B. it is apparent that the minimum heat production during inanition is not far from 0.0167 calorie per kilogram of body-weight, or 0.52 calorie per square meter of body surface per minute.

Relation between relative humidity, water of oxidation of organic hydrogen, and total heat production.—The water of oxidation of organic hydrogen includes all the organic hydrogen of the protein, fat, and glycogen katabolized. It is, therefore, roughly speaking, a measure of the total katabolism during the day, and since the total katabolism determines the heat production, there should be more or less constant ratios between these two factors. In table 242 are recorded the relative humidity, the water of oxidation of organic hydrogen, and the total heat production.

The relative humidity and its influence on the water of vaporization has already been discussed (see p. 428). The conditions determining the relative humidity inside this type of respiration chamber present certain features of unusual interest. The ventilating air-current enters the respiration chamber absolutely dry. The body of the subject gives off water continuously to this air, and, depending upon the rate of ventilation and muscular activity and consequent water output of the subject, the relative humidity may vary. In all the experiments the rate of ventilation was practically constant (see p. 429), but the influence of internal and external muscular activity (measured by the total heat production) on the variations in relative humidity is worthy of note. In general, the relative humidity decreases with a diminution in the total heat production and increases with a rise in the heat production, although it may be noted that in experiments with the same subject a marked variation in the relative humidity of the air inside the chamber may occur on different days of the different experiments when the total heat production

[109] The special question of the influence of heat production during fever will be discussed in a later report.

does not vary. Thus, on the second day of experiment No. 71 with S. A. B., the relative humidity was 36.6 per cent and the total heat production was 1844 calories while on the third day of experiment No. 77, the total heat production was 1840 calories and the relative humidity only 30.2 per cent. Such a lack of agreement is even more noticeable in the experiments with different subjects. Thus, on the second day of experiment No. 80, the relative humidity was 54 per cent and the total heat production 2099 calories, while on the first day of experiment No. 85, the total heat production was 2109 calories and the relative humidity 35.6 per cent. In spite of these gross fluctuations there is a tendency, however, for the relative humidity to vary with the total heat production.

The fluctuations in the amounts of water resulting from the oxidation of organic hydrogen are remarkably comparable with those of the total heat production, especially after the first day of the fast. The relation between these two products bears out the assertion made previously, that the metabolism on the first day of fasting can not be considered as true fasting metabolism. From the average of these experiments with and without food, it is seen that each gram of water of oxidation of organic hydrogen is accompanied by the production of 9.1 calories and every gram of organic hydrogen oxidized is accompanied by a heat production amounting to 82.4 calories.

OXYGEN AND CARBON DIOXIDE THERMAL QUOTIENTS.

The number of grams of carbon dioxide produced and oxygen absorbed per 100 calories of heat, the so-called carbon dioxide and oxygen thermal quotients, are recorded for experiments with and without food in table 243.

The oxygen thermal quotients show that for every 100 calories of heat there were about 30 grams of oxygen absorbed. The accuracy of the determinations of oxygen with this apparatus have been found by check tests, to be within 1 per cent. It is evident that this error allows a fluctuation of from 29.8 to 30.2 in the thermal quotient. In the majority of cases it is believed that the oxygen was determined to within 1 per cent and therefore the values given are of significance. It is, nevertheless, a fact that the determination of the carbon dioxide is much less difficult than that of oxygen, and consequently for any comparison between the heat and oxygen or carbon dioxide the latter factor must be considered the more accurate. The lowest oxygen thermal quotient recorded is 28.84 on the third day of experiment No. 77, and the highest is 31.37 on the last day of experiment No. 73.

TABLE 242.—*Daily relative humidity, and daily heat production in metabolism experiments with and without food.*

Experiment number.	Subject and date.	Relative humidity.	Water of oxidation of organic hydrogen.	Total heat production.
	Experiments without food.			
59..	B.F.D., 1903:	*P. ct.*	*Gms.*	*Cals.*
	Dec. 18–19....	46.9	229	2080
	Dec. 19–20....	44.4	223	2107
	Dec. 20–21....	43.5	222	2102
63..	A.L.L., 1904:			
	Apr. 27–28....	49.1	241	2167
	Apr. 28–29....	48.8	237	2217
69..	A.L.L., 1904:			
	Dec. 16–17....	45.0	221	1951
	Dec. 17–18....	51.5	231	2163
	Dec. 18–19....	48.0	221	2035
	Dec. 19–20....	43.7	213	1958
71..	S.A.B., 1905:			
	Jan. 7– 8....	45.0	235	1970
	Jan. 8– 9....	36.6	200	1844
	Jan. 9–10....	33.5	191	1746
	Jan. 10–11....	30.8	176	1606
73..	S.A.B., 1905:			
	Jan. 28–29...	36.3	210	1866
	Jan. 29–30....	31.4	196	1791
	Jan. 30–31....	30.9	188	1739
	Jan. 31–Feb. 1.	29.0	180	1663
	Feb. 1– 2....	27.9	170	1548
75..	S.A.B., 1905:			
	Mar. 4– 5....	32.3	195	1765
	Mar. 5– 6....	29.0	189	1768
	Mar. 6– 7....	29.4	187	1797
	Mar. 7– 8....	27.2	185	1775
	Mar. 8– 9....	26.4	173	1649
	Mar. 9–10....	24.4	166	1553
	Mar. 10–11....	25.1	164	1568
77..	S.A.B., 1905:			
	Apr. 8– 9....	30.5	208	1874
	Apr. 9–10....	30.7	202	1880
	Apr. 10–11....	30.2	192	1840
	Apr. 11–12....	29.7	188	1807
79..	H.E.S., 1905:			
	Oct. 13–14....	57.0	220	1951
	Oct. 14–15....	61.2	215	2047
	Experiments without food.			
80..	C.R.Y., 1905:	*P. ct.*	*Gms.*	*Cals.*
	Oct. 27–28....	51.8	217	1954
	Oct. 28–29....	54.0	224	2099
81..	A.H.M., 1905:			
	Nov. 21–22....	30.6	185	1729
	Nov. 22–23....	31.2	178	1781
82..	H.C.K., 1905:			
	Nov. 24–25....	38.8	256	2222
	Nov. 25–26....	41.2	261	2477
83..	H.R.D., 1905:			
	Dec. 5–6.....	33.5	209	1914
	Dec. 6–7......	32.2	197	1907
85..	N.M.P., 1905:			
	Dec. 9–10....	35.6	240	2109
	Dec. 10–11....	40.1	252	2305
89..	D.W., 1906:			
	Jan. 10–11....	38.8	248	2150
	Jan. 11–12....	38.8	244	2254
	Experiments with food.			
70..	A.L.L., 1904:			
	Dec. 20–21....	45.0	226	2104
	Dec. 21–22....	48.0	244	2228
	Dec. 22–23....	50.5	275	2457
72..	S.A.B., 1905:			
	Jan. 11–12....	32.0	184	1676
74..	S.A.B., 1905:			
	Feb. 2–3......	30.0	184	1691
	Feb. 3–4......	28.7	184	1585
	Feb. 4–5......	29.6	187	1607
76..	S.A.B., 1905:			
	Mar. 11–12....	27.2	191	1767
	Mar. 12–13....	26.5	194	1728
	Mar. 13–14....	26.6	206	1758
	Average of all experiments.	....	209	1911

TABLE 243.—*Oxygen and carbon dioxide thermal quotients in metabolism experiments with and without food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.
59...	B.F.D., Dec. 18 to 20, 1903:							
	Oxygen..........	30.25	29.87	30.74	....	....	....	....
	Carbon dioxide...	**32.23**	**31.28**	**30.94**	....	....	....	....
68...	A.L.L., Apr. 27 to 28, 1904:							
	Oxygen..........	29.53	28.98	....	....	....	....	....
	Carbon dioxide...	**32.04**	**30.63**	....	....	....	....	....
69...	A.L.L., Dec. 16 to 19, 1904:							
	Oxygen..........	29.94	29.86	30.43	30.70	....	....	....
	Carbon dioxide...	**32.38**	**30.81**	**31.48**	**31.29**	....	....	....
70...	A.L.L., Dec. 20 to 22, 1904:							
	Oxygen..........	29.59	30.19	29.83	....	....	....	....
	Carbon dioxide...	**31.03**	**30.83**	**31.64**	....	....	....	....
71...	S.A.B., Jan. 7 to 10, 1905:							
	Oxygen..........	29.90	30.05	30.81	30.69	....	....	....
	Carbon dioxide...	**33.96**	**30.92**	**31.72**	**31.65**	....	....	....
72...	S.A.B., Jan. 11, 1905:							
	Oxygen..........	30.83	....	....	....	....	....	....
	Carbon dioxide ...	**31.29**	....	....	....	....	....	....
73...	S.A.B., Jan. 28 to Feb. 1, 1905:							
	Oxygen..........	29.17	30.59	30.65	30.23	31.37	....	....
	Carbon dioxide...	**32.64**	**31.27**	**31.15**	**30.98**	**31.15**	....	....
74...	S.A.B., Feb. 2 to 4, 1905:							
	Oxygen..........	30.28	30.86	30.81	....	....	....	....
	Carbon dioxide...	**31.25**	**33.42**	**32.82**	....	....	....	....
75...	S.A.B., Mar. 4 to 10, 1905....							
	Oxygen..........	30.24	30.22	29.81	29.26	29.78	30.01	29.75
	Carbon dioxide	**32.29**	**31.14**	**30.33**	**30.09**	**30.10**	**30.74**	**30.33**
76...	S.A.B., Mar. 11 to 13, 1905:							
	Oxygen..........	29.84	28.94	28.92	....	....	....	....
	Carbon dioxide...	**31.20**	**32.43**	**34.70**	....	....	....	....
77...	S.A.B., Apr. 8 to 11, 1905:							
	Oxygen..........	29.66	30.41	28.84	29.41	....	....	....
	Carbon dioxide...	**31.98**	**30.69**	**30.25**	**30.14**	....	....	....
79...	H.E.S., Oct. 13 to 14, 1905:							
	Oxygen..........	29.51	29.57	....	....	....	....	....
	Carbon dioxide...	**32.39**	**31.03**	....	....	....	....	....
80...	C.R.Y., Oct. 27 to 28, 1905:							
	Oxygen..........	29.49	29.94	....	....	....	....	....
	Carbon dioxide...	**32.11**	**30.50**	....	....	....	....	....
81...	A.H.M., Nov. 21 to 22, 1905:							
	Oxygen..........	29.90	29.60	....	...	....	....	....
	Carbon dioxide...	**30.93**	**29.45**	....	....	...	....	....
82...	H.C.K., Nov. 24 to 25, 1905:							
	Oxygen..........	29.85	29.62	....	....	....	....	....
	Carbon dioxide...	**33.35**	**30.97**	....	....	....	....	....
83...	H.R.D., Dec. 5 to 6, 1905:							
	Oxygen..........	30.58	29.07	....	....	....	....	....
	Carbon dioxide...	**31.70**	**30.37**	....	....	...	....	....
85...	N.M.P., Dec. 9 to 10, 1905:							
	Oxygen.........	29.76	29.31	....	....	....	....	....
	Carbon dioxide...	**33.03**	**31.21**	....	....	....	....	....
89...	D.W., Jan. 10 to 11, 1906:							
	Oxygen..........	30.01	30.22	....	....	...	....	....
	Carbon dioxide...	**33.60**	**31.30**	....	....	....	....	....

The absorption of oxygen results in the combustion of carbon in the case of glycogen assuming that the oxygen of the carbohydrate molecule combines with the hydrogen,[1] and the combustion of carbon and organic hydrogen in the case of fat and protein, and hence it would be expected that the oxygen thermal quotient would vary with the proportions of protein, fat, and glycogen consumed. Since the widest fluctuations in the relative proportions of these compounds occur on the first day of the experiments, the oxygen thermal quotients would be expected to be less regular on the first day than on other days of the fasts. It will be noticed that the highest and lowest quotients were observed on the third and fifth days of fasting. This fact is of importance in the subsequent comparison of the heat production with the estimated energy of the material oxidized in the body (see p. 514). When the relative proportions of protein, fat, and carbohydrate become more nearly established as on the second and subsequent days, the quotient should remain practically constant, although the fact must not be lost sight of that there are relatively wide variations in the proportions of glycogen and fat katabolized even on some of the later fasting days. Making due allowance, however, for such deviations, it is clear that marked variations in the oxygen thermal quotients in the later days of fasting are due to one of two things, defective oxygen determinations or defective heat measurements. A further discussion of the relation of oxygen and heat production is given on page 515.

The carbon dioxide thermal quotient, like that of the oxygen is determined by the nature of the material burned. The larger the amount of glycogen, the greater the amount of carbon dioxide produced per 100 calories of energy. Consequently we would expect to find on the first day of fasting, where the greater amount of glycogen is consumed, the larger carbon dioxide thermal quotient. It is important to recognize that in comparing these quotients the variations in the total 24 hours' heat production from experiment to experiment are without significance. In general, the carbon dioxide thermal quotients are greatest on the first day of the fast. After the relative proportions of protein, glycogen, and fat katabolized in the body have attained a constancy, the quotient has a tendency to remain constant, in general not far from 30.7. The lowest carbon dioxide-thermal quotient observed in any of the experiments is 29.45 on the second day of experiment No. 81 and the highest 34.70 on the third day of food experiment No. 76.

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[1] The assumption that the absorbed oxygen combines *only* with carbon is obviously untenable.

COMPARISON OF ALL FACTORS OF KATABOLISM.

The different relations between the carbon dioxide and heat, and the methods of expressing the output per square meter of body surface and per kilogram of body-weight computed and tabulated in this report are those which have been

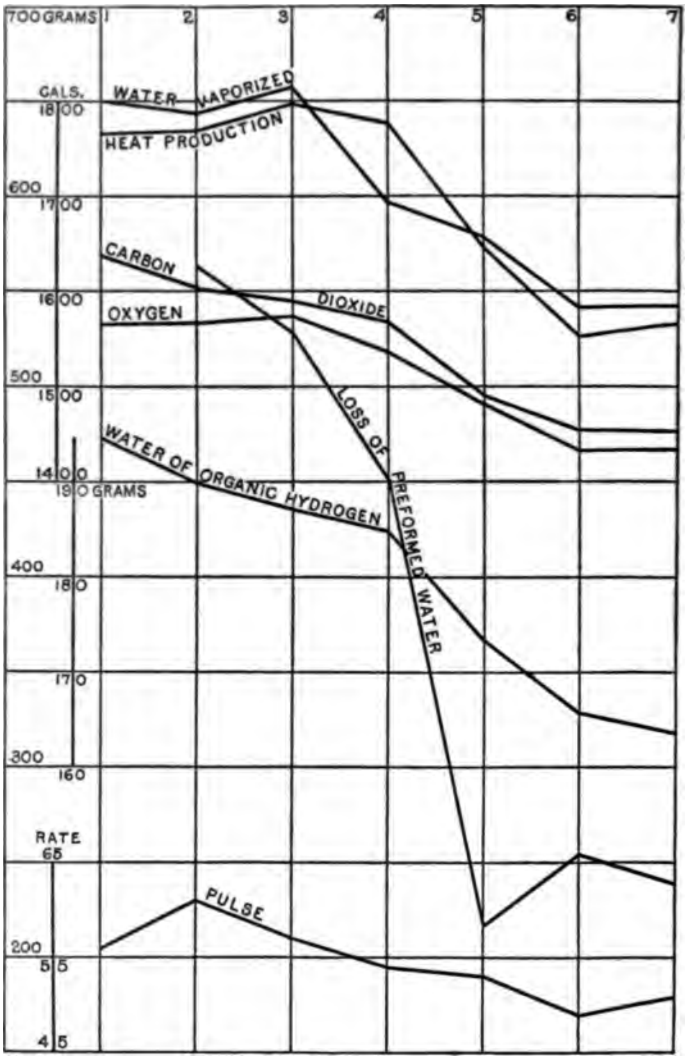

FIG. 3.

found by comparison to be most commonly used in the reports of experiments of a similar nature made in other laboratories. Obviously, various other relations can be computed and it is believed that the data given in the preceding

section of this report furnish all the statistical details for such computations as may be desired.

The method of showing the relative katabolism by curves has been elaborated

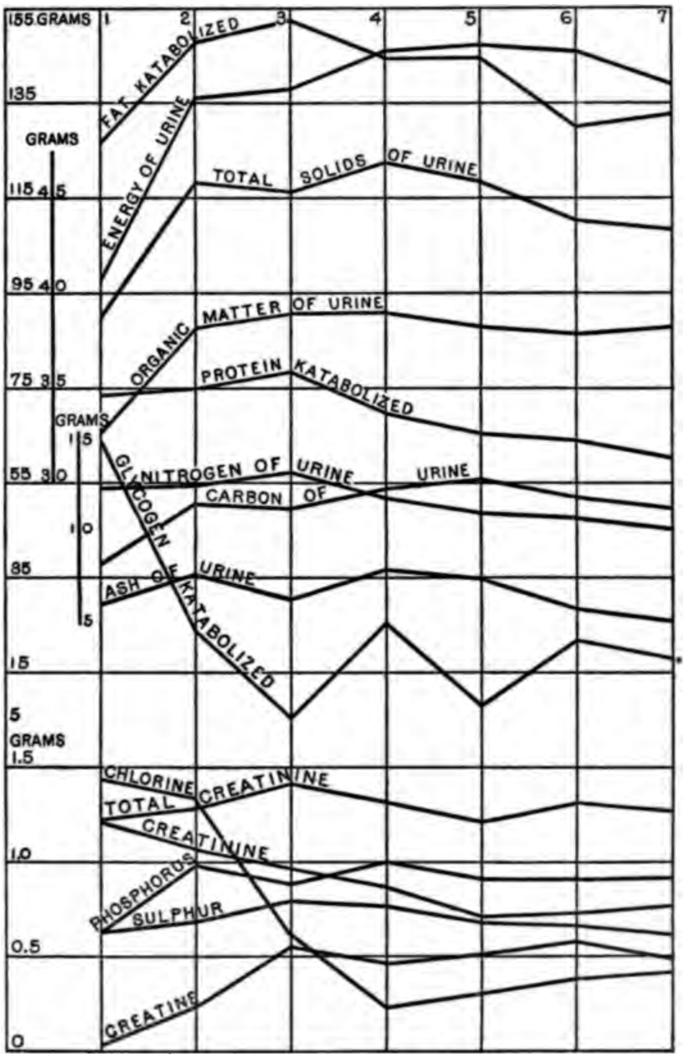

FIG. 4.

for one typical experiment (No. 75—a seven days fast), and the results are given in the two curves herewith.

The curves are in large part self-explanatory. The uniformity between the curves for water vaporized, heat production, carbon dioxide, oxygen, water of

organic hydrogen, and pulse is especially well marked. It would appear, the that these factors of katabolism are in a general way directly proportional the pulse rate even with the inadequate records made in this experiment, a this curve emphasizes more perhaps than could any series of figures, the i portance of making records of pulse rate in metabolism experiments. Anti pating this extreme regularity between the pulse rate and the factors of met bolism, in the experiments Nos. 79 to 89 inclusive especial care was taken secure the pulse and respiration rate (see p. 228). The protein, fat, a glycogen katabolized and the amounts of the urinary constituents are shown the second set of curves. The curve for the protein obviously follows direct the nitrogen of urine. The relation between the katabolism of fat and glyc gen is shown, since as the katabolism of glycogen decreases, the fat kataboliz increases in nearly every instance. The energy of the urine follows in a gener way the organic matter and the carbon, but there is little, if any, relation b tween the nitrogen and the other factors in the urine.

ENERGY BALANCE.

The increased accuracy in the apportionment of the katabolism between tl three compounds—protein, fat, and carbohydrate—in the experiments durin inanition, makes the estimate of the energy of material katabolized from tl body much more accurate than in the older experiments in which there w no exact knowledge of the amounts of glycogen katabolized, and in all prob bility the estimated energy of material oxidized in the body computed from th amounts of protein, fat, and glycogen katabolized results in much closer appro imations to the actual energy transformations than have as yet been availabl to physiologists.

In the experiments during inanition previously reported from this labora tory[179] the estimated energy of material katabolized was compared with th heat production. The store of glycogen in this comparison was assumed t have remained unaltered. Furthermore, while the heat elimination was in a probability determined with reasonable accuracy the heat production was no measured as accurately as in the present series of fasting experiments.

The results show that the differences in three experiments between the esti mated energy from material actually oxidized and the net heat outgo were some what over 100 calories. In these three experiments (Nos. 36, 39, and 42), th energy measured as heat was less than the estimated energy of materia actually oxidized in the body. The percentage error was —5.1, —5.4, an —5.2 per cent for the three experiments, respectively. On the other hand on the 2 days of experiment No. 51, the agreement between the energy o material actually oxidized and that measured as heat was extremely close No wholly satisfactory explanation appears at present for this agreement

[179] U. S. Dept. Agr., Office of Expt. Sta. Bul. 136.

Experiment No. 51 immediately followed a 1-day experiment, No. 50, in which the subject was distinctly ill. He was compelled to stop the work experiment in which he was engaged and lie down during the day, consuming but a small quantity of food. Therefore, the effect of the preliminary day before the 2 days of fasting may have been such as to cause errors either in the results of analyses or the heat measurements. There is a strong probability, too, that after the severe muscular work on the 3 days preceding experiment No. 50, the store of glycogen in the body had been heavily drawn upon and, therefore, did not undergo material alteration during fasting. Against this latter supposition is the fact that for the 3 days of experiment No. 49, although the subject worked very severely, he was supplied with a very large amount of carbohydrates in the diet, and analyses showed that during the last 2 days of the experiment, there was a small gain of carbon to the body. On the contrary, there was a marked loss of carbon with probably heavy drafts upon previously-stored glycogen in the 1-day experiment No. 50, which immediately preceded the 2 days of fast. The results, then, in all of the earlier experiments would imply that a very material error is present when the assumption is made that the glycogen content of the body remains constant, save in experiments where the store of glycogen has previously been considerably depleted.

Since the apparatus used in connection with these experiments permitted the direct measurement of heat, the estimated energy of material oxidized from the body can be compared directly with the heat production, and since the law of the transformation of energy holds true in the human body, the accuracy of the method of estimating the heat production from the total katabolism can be checked. For purposes of comparison, the estimated energy of katabolized body material, the total heat production, and the differences between the total heat production and the energy from body material, expressed both in terms of calories and per cent, are given in table 244.

The widest discrepancy noted on any day during inanition is on the fifth day of experiment No. 73 where the estimated energy of katabolized body material was 66 calories greater than the total heat production, a discrepancy amounting to + 4.3 per cent. On the last 2 days of experiment No. 74 (with food), there were discrepancies of +4.3 and +3.9 per cent, respectively. Usually the discrepancies are extremely small. Thus in the average of 43 days of experiments without food, the estimated energy of katabolized body material, 1937 calories, was but 13 calories greater than the average total heat production, a discrepancy of + 0.7 per cent. A somewhat greater discrepancy was observed in the smaller number of food experiments, the estimated energy from body material, 1879 calories, being 20 calories greater than the total heat production, corresponding to a discrepancy of + 1.1 per cent. The average for all the experiments here published covering 53 days, with and without food, shows a discrepancy of + 0.7 per cent.

TABLE 244.—*Comparison of computed and measured heat production, in metaboli experiments with and without food.*

Experiment number.	Subject and date.	Estimated energy of katabolized body material.	Total heat production.	Energy from body material greater (+ or less (—) than outpu: Amount.	Proportio
	Experiments without food.				
59......	B.F.D., 1903:	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
	Dec. 18–19	2122	2080	+42	+2.0
	Dec. 19–20	2115	2107	+ 8	+0.4
	Dec. 20–21	2159	2102	+57	+2.7
68......	A.L.L., 1904:				
	Apr. 27–28	2181	2167	+14	+0.6
	Apr. 28–29	2179	2217	−38	−1.7
69......	A.L.L., 1904:				
	Dec. 16–17	1972	1951	+21	+1.1
	Dec. 17–18	2166	2163	+ 3	+0.1
	Dec. 18–19	2069	2035	+34	+1.7
	Dec. 19–20	2008	1958	+50	+2.6
71......	S.A.B., 1905:				
	Jan. 7– 8	2013	1970	+43	+2.2
	Jan. 8– 9	1860	1844	+16	+0.9
	Jan. 9–10	1800	1746	+54	+3.1
	Jan. 10–11	1653	1606	+47	+2.9
73......	S.A.B., 1905:				
	Jan. 28–29	1847	1866	−19	−1.0
	Jan. 29–30	1831	1791	+40	+2.2
	Jan. 30–31	1782	1739	+43	+2.5
	Jan. 31–Feb. 1	1678	1663	+15	+0.9
	Feb. 1– 2	1614	1548	+66	+4.3
75......	S.A.B., 1905:				
	Mar. 4– 5	1796	1765	+31	+1.8
	Mar. 5– 6	1790	1768	+22	+1.2
	Mar. 6– 7	1785	1797	−12	−0.7
	Mar. 7– 8	1734	1775	−41	−2.3
	Mar. 8– 9	1636	1649	−13	−0.8
	Mar. 9–10	1547	1553	− 6	−0.4
	Mar. 10–11	1546	1568	−22	−1.4
77......	S.A.B., 1905:				
	Apr. 8– 9	1885	1874	+11	+0.6
	Apr. 9–10	1910	1880	+30	+1.6
	Apr. 10–11	1775	1840	−65	−3.5
	Apr. 11–12	1770	1807	−37	−2.0
79......	H.E.S., 1905:				
	Oct. 13–14	1961	1951	+10	+0.5
	Oct. 14–15	2046	2047	− 1	....
80......	C.R.Y., 1905:				
	Oct. 27–28	1974	1954	+20	+1.0
	Oct. 28–29	2125	2099	+26	+1.2
81......	A.H.M., 1905:				
	Nov. 21–22	1751	1729	+22	+1.3
	Nov. 22–23	1763	1781	−18	−1.0

TABLE 244.—*Comparison of computed and measured heat production, in metabolism experiments with and without food*—Continued.

Experiment number.	Subject and date.	Estimated energy of katabolized body material.	Total heat production.	Energy from body material greater (+) or less (—) than output. Amount.	Proportion.
82......	H.C.K., 1905:	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
	Nov. 24–25.................	2261	2222	+39	+1.8
	Nov. 25–26.................	2494	2477	+17	+0.7
83......	H.R.D., 1905:				
	Dec. 5–6....................	1960	1914	+46	+2.4
	Dec. 6–7....................	1855	1907	—52	—2.7
85......	N.M.P., 1905:				
	Dec. 9–10...................	2117	2109	+ 8	+0.4
	Dec. 10–11..................	2273	2305	—32	—1.4
89......	D.W., 1906:				
	Jan. 10–11..................	2197	2150	+47	+2.2
	Jan. 11–12..................	2284	2254	+30	+1.3
	Experiments with food.				
70......	A.L.L., 1904:				
	Dec. 20–21..................	2089	2104	—15	—0.7
	Dec. 21–22..................	2253	2223	+30	+1.3
	Dec. 22–23..................	2474	2457	+17	+0.7
72......	S.A.B., 1905:				
	Jan. 11–12..................	1727	1676	+51	+3.0
74......	S.A.B., 1905:				
	Feb. 2–3....................	1711	1691	+20	+1.2
	Feb. 3–4....................	1653	1585	+68	+4.3
	Feb. 4–5....................	1669	1607	+62	+3.9
76......	S.A.B., 1905:				
	Mar. 11–12..................	1772	1767	+ 5	+0.3
	Mar. 12–13..................	1699	1728	—29	—1.7
	Mar. 13–14..................	1743	1753	—10	—0.6
	Average of experiments: Without food (43 days).	1937	1924	+13	+0.7
	With food (10 days).....	1879	1859	+20	+1.1
	All experiments (53 days)	1926	1912	+14	+0.7

Discrepancies such as appear in certain of the experiments between the estimated energy of katabolized body material and the total heat production may be caused by a number of factors. The assumptions involved in the computations as used with the present form of apparatus are (1) that there are no differences in the amounts of partially oxidized material in the body at the end of each day; and (2) that the material in the urine represents the incompletely oxidized nitrogenous fragment of the protein molecule. The influence of any

errors involved in these assumptions on the total metabolism can hardly be estimated with our present knowledge of physiological chemistry. Since for the average of all the experiments, the discrepancy between the computed and measured heat production is almost insignificant, it would appear that it is reasonable to assume that in the few instances where noticeable discrepancies appear there are specific errors other than those involved in the assumptions above outlined, which have inevitably crept into the chemical and physical measurements. Fortunately, the simultaneous determination of the oxygen absorbed and carbon dioxide and heat production furnishes an unusual check on the accuracy of the method in general and the computations in particular. From the ratios between the oxygen and carbon dioxide and the heat, clues regarding the causes of the few marked discrepancies observed in the comparisons may be obtained. It is necessary, therefore, to compare the data given in table 244 with those in table 243. The most noticeable discrepancies between the computed energy of body material and the total heat production are to be observed on the last day of experiment No. 73, the third day of experiment No. 77, and the last 2 days of experiment No. 74. Examining the carbon dioxide and oxygen thermal quotients for these days, certain valuable conclusions may be drawn. Thus, on the fifth day of experiment No. 73, the oxygen thermal quotient is abnormally high while the carbon dioxide thermal quotient is approximately normal for this particular experiment. Hence, on this day, at least, the figures point strongly to the conclusion that there was an error in the oxygen determination rather than in the heat determination, and consequently the discrepancy of +4.3 per cent implies that the heat production was accurately determined while the estimated energy of katabolized body material was somewhat too high. Again, on the third day of experiment No. 77, the oxygen thermal quotient is abnormally low while the corresponding carbon dioxide thermal quotient is not abnormal. It is evident, then, that in this case the error is again with the determination of oxygen, so that the total heat production is probably not far from correct. Another factor enters into food experiment No. 74. The oxygen-thermal quotient is high on both days but the carbon dioxide thermal quotient is likewise abnormally high, hence it would appear that on these 2 days the error is with the measurement of heat rather than the computed products of katabolism. It is of course not impossible that minor compensating errors may enter into the comparison of these three factors, but certainly the simultaneous determination of the carbon dioxide elimination, oxygen consumption, and heat production is of the greatest value in deducing the correct balance between the total heat production and the estimated energy of katabolized body material. It is, furthermore, significant that none of the ratios seem to point toward marked discrepancies in the carbon dioxide determination, bearing out the results of check tests which show that the carbon dioxide determinations with this apparatus are extremely

accurate. While, then, it is possible with accurate determinations of carbon dioxide and oxygen, in addition to the ultimate analyses of the urine, to compute the total heat production with an accuracy in all probability well within 2 or 3 per cent and with a large number of experiments an average accuracy of less than 1 per cent, accurate heat measurements are essential in any study of the energy transformations in the body. The carbon dioxide determination alone is insufficient, likewise the oxygen determination, although it would appear that the relation between the oxygen consumption and heat production is much more constant on the different days of the fast than that between the carbon dioxide output and heat production.

From the molecular weights and heats of combustion of fat and carbohydrate the amount of energy liberated when 1 gram of oxygen is used to burn either of these bodies may be computed. The energy resulting from the combustion of 1 gram of carbon in the form of fat or carbohydrate may also be found. From the results of the computations it will be seen that the heat production per gram of oxygen in the combustion of both fat and carbohydrate is nearly the same, while the heat production per gram of carbon dioxide produced is considerably more in the case of the combustion of fat than in the combustion of carbohydrate. Hence, it can be seen that irrespective of whether fat or glycogen is burned in the body, the energy production per gram of oxygen consumed will always be nearly the same, while the energy output per gram of carbon dioxide will vary, depending upon the relative amounts of fat and carbohydrate oxidized.

Theoretically, there should be no discrepancy between the estimated energy of the material oxidized in the body and the total heat production, when computed from factors as accurately determined as were the nitrogen, carbon dioxide, and oxygen of these experiments. The fact remains, however, that experiments of this nature are being made with an extremely intricate and complex organism and not in a test tube or flask. The probable limit of error we have arbitrarily set as not far from 1.5 per cent. About half of these experiments come inside of this estimated limit of error, and yet during fasts the assumptions regarding the intermediary metabolism are greater perhaps than in any other class of experiments. On the whole it is doubtful if the experiments could have been conducted so as to secure much closer agreement. Certain known errors which could not be properly corrected unavoidably crept into certain of the experiments. The carbon dioxide and oxygen thermal quotients, however, suggest strongly the nature of the error in all experiments with marked discrepancies. Undoubtedly many other unknown errors likewise found their way into the conduct of the experiments and the computations. On the whole, however, there is an agreement between the computed energy and that directly determined that is as satisfactory as physiological experiments could ordinarily demand.

EXPERIMENTS WITH FOOD.

All the observations made on man during inanition would imply that during a prolonged fast the whole alimentary tract is quiescent.[m] Consequently the ingestion of food after a prolonged fast would naturally be expected to result in a more marked stimulation of peristalsis and metabolism in general, and at first sight it would appear that a study of the influence of the ingestion of food could best be made immediately after a prolonged fast.

Data regarding the influence of the ingestion of food can be obtained in three different ways: (1) by studying the influence on the digestion of food in general, with special reference to the effect of the long quiescence of the alimentary tract on the degree of the absorption of food materials after fasting; (2) by observing the effect on the total metabolism of the ingestion of food after fast; and (3) by studying the course of the recovery of the body to its normal condition including both a study of the length of time required for recovery and the extent to which the losses during inanition were compensated. This problem is closely related to that attending study of recoupment after fever.

The first of these methods demands for its success that the amount of food ingested be large, and that a correct separation of the feces be obtained. The large amounts of food are necessary to produce the maximum effect and likewise to produce a sufficient amount of feces to permit proper separation. If the normal conditions of metabolism are established in a few days, in order to notice the particular effect of the transition the metabolism should be most carefully studied on the first day.

It is practically impossible even under the most advantageous conditions of experimenting to separate the feces corresponding to the food of any one day. In experiments in which a special diet is ingested for 2 days, the separation may be made, although only with considerable difficulty. But when the previous period has been one of inanition, with the delayed expulsion of fecal matter belonging to the food period prior to the fast, the difficulties of separating the feces for 2 or even 3 days are considerably increased.

The second method of study, namely, observation of the effect on the total metabolism to be observed during the height of digestion, should also be accompanied with large amounts of food; for as has been shown by a number of other researches in which the respiratory quotient has been the criterion, the effect of the ingestion of food is relatively not large, and consequently the quantities of food ingested in experiments of this kind should be as large as possible.

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[m] Boldireff (Archives des Sciences Biologiques (1905), 11, p. 1) has, however, noted periodical movements of the intestine even when no food has been ingested.

The third method, namely, study of the course of the recovery after fasting, obviously requires a longer time than the 2 or 3 days' sojourn in the respiration calorimeter after a fasting period. It is necessary, therefore, to resort to studies of metabolism which can be made outside of the respiration chamber, namely, those of the intake and output of nitrogen, sulphur, phosphorus, etc., and such studies as have been made with S. A. B., in connection with these experiments receive special discussion beyond.

Unfortunately, the effect of the ingestion of food immediately after the fast could not be studied in these experiments under conditions which even approximated the ideal conditions outlined above. In connection with the fasting experiments here reported four experiments in which food was ingested were made, during which the subjects remained inside the respiration chamber continuously from 1 to 3 days. It was soon seen that a practical difficulty was experienced that had not been anticipated, namely, that it was difficult, if not indeed dangerous, to administer a large amount of food on the first day following a fast. Consequently, the quantity of food administered had to be very much restricted and the effect on metabolism and digestibility was correspondingly diminished. Usually not until the second day after the fast could any considerable amount of food be taken. Thus the important observations on the first day were made under great disadvantages.

Furthermore, the separation of feces was in every case extremely difficult. While no difficulty was experienced in the separation at the end of the food period, the sharp separation of the feces properly apportioned to the food period from the mass of fecal matter that had been retained in the colon during the whole of the fast was extremely difficult. The feces that had been for a long time in the alimentary tract had been deprived of their water, so that, at least in one instance, the water content was as low as 50 per cent. This mass became more or less mixed with the softer, fresher feces as they were forced through the colon and it was separated after expulsion only with difficulty. Under these circumstances, then, the results obtained during the 3-day calorimeter experiments in studying the problem of the effect of the ingestion of food after fasting from the standpoint of the influence on digestibility and on the total metabolism have a value considerably less than it was hoped they would have.

It was, furthermore, apparent that this method of studying the effect of the ingestion of food after fasting was impracticable, and that an entirely different type of experiment must be used for a proper study of this problem. Accordingly, during the past year experiments have been in progress in this laboratory in which large quantities of food were ingested after a short fast (12 to 18 hours) rather than after a period of inanition covering several days.

The method of studying the effect of the ingestion of food after a short fast was suggested by the data secured in the fasting experiments here reported.

These data seemed to indicate that in general the fasting katabolism is reached after 24 hours of inanition. The results of the experiments on food ingestion after short fasts will be published in a subsequent report. Since these embody a type of experiment somewhat different from the food experiments here reported, it seems best to include with the fasting experiments the data obtained from the food experiments immediately following them.

The results obtained have much general interest other than that regarding the matter of digestibility or the effect on general metabolism, and although the special discussion of the effect of the ingestion of food on metabolism will be taken up in a subsequent publication certain features are here discussed. Furthermore, in the discussion of the fasting experiments the data for the subsequent days with food have frequently been inserted in the derived tables for the purpose of comparison. Thus, some discussion of the effect of ingestion of food has already been given. It is the purpose of this discussion to outline some of the more important points to be emphasized in connection with the data for food experiments Nos. 70, 72, 74, and 76.

Aside from the data obtained from the experiments with food inside the respiration chamber, the data for the food, feces, and urine were obtained for periods of considerable length following food experiment No. 76 and fasting experiment No. 77, and many interesting data on the third point, i. e., recoupment after fasting, were secured.

In these experiments the total income of food and the outgo in urine and feces were determined. Since the primary object was to study the intake and output of nitrogen, they have been designated Nitrogen Metabolism Experiments, Nos. 1 and 2.

The results of these experiments on the long-continued ingestion of food are here presented and discussed. The detailed statistical data have been given on pages 274 to 299.

PRECAUTIONS IN FEEDING.

It is commonly considered among professional fasters and others whose experience with fasting subjects has been extended, that especial caution should be exercised in administering food after a fast. The ingestion of a large amount of solid food into the stomach after a long period of rest, causes serious disturbance. Hence, in the experiments reported herewith, special care was taken to avoid any complications which might result from over-feeding. In general, the subjects were given small amounts of milk (less than half a glass) from time to time, and no solid food was administered until several hours after the fast ended. The previous experience of the subject S. A. B. had convinced him that his fasts were best broken by taking orange juice. Hence, his diet for the first day contained only orange juice and small quantities of milk. In subsequent experiments, the orange juice was supplemented by a small amount

of apple and in one case by a solid food in the shape of gluten crackers and shredded wheat. After fasting experiment No. 77, the subject did not remain in the chamber and his diet for that day taken outside of the chamber was chosen at will. During the day he consumed milk, bread, tomatoes, lemons, and oranges, but the total quantity of food ingested was small, furnishing but 43.47 grams of protein, and 1311 calories of energy (see table 176). On the next day the quantity of protein and energy was more than doubled, while on the third day, the subject consumed 120 grams of protein and 3649 calories of energy. The food experiments inside the respiration calorimeter which followed certain of the fasting experiments, formed only a transitional period from fast to complete food, inasmuch as the diet consumed was generally limited, especially as regards protein. Thus, in experiment No. 76, the food furnished but 37.6 grams of protein and 1841 calories of energy per day, and while the energy was sufficient to meet the requirements of the body during the inactive period in the calorimeter, the protein was not sufficient to equalize the draft upon body protein.

On the first day after food experiment No. 76, i. e., the fourth day after the end of the fast, the subject consumed a diet furnishing 131.5 grams of protein and 5064 calories of energy, and on the following day, the amounts were even larger, i. e., 167.5 grams of protein and 6612 calories of energy.

While, therefore, the subjects were unable to consume large amounts of food on the first day after fast, there seemed to be no difficulty in ingesting large quantities on the second day. This is especially noticeable on the second day after experiment No. 77, as has been pointed out above.

THE DIGESTIBILITY OF FOOD AFTER INANITION.

The experiments with food which followed the fasting experiments in the respiration calorimeter furnish some data regarding the digestibility of food material after fasting. It is conceivable that after a long period of rest the stimulus due to the ingestion of food would result in an excessive flow of the digestive juices and increased peristalsis, and in an expulsion of feces from the colon. On the other hand, the quantity of fecal material required to distend the colon before defecation might result in a delay in the expulsion of feces. The feces from ordinary digestion experiments are preceded by feces of a character not especially different from those to be analyzed. Thus, separation between the experimental feces and those resulting from the food preceding is not based upon physical condition. Regularity in the time of meals and the amounts taken is also of importance in securing uniform consistency of the feces. The irregularity in the ingestion of food, especially on the first day following fasting, is one of a number of factors which tend to hinder the accurate separation of feces. The small amounts of food ingested on the first day, in some instances containing only 38 grams of protein,

obviously increase markedly the percentage error, since any slight error in the separation of feces would affect materially the coefficient of digestibility of protein.

Diet.—Milk was the chief article of diet in this series of food experiments in the calorimeter. In the nitrogen metabolism experiments a very much more elaborate selection of foods was made, but they consisted in large part of milk, cream, fruit, and vegetables, although occasionally meat was taken.

Feces.—In the discussion of feces after fasting it was pointed out that in none of the calorimeter experiments here reported was there a sufficiently sharp and accurate separation of feces made to enable any special quantity to be designated as fasting feces. In only one instance was there any approximation to such a separation and a subsequent consideration of the digestibility of the food in the period following fast shows that in all probability the so-called fasting feces were in reality a portion of the feces resulting from food preceding the experiment.

Separation of feces.—It has already been stated that much difficulty was experienced in obtaining sharp separations of the feces. In ordinary digestion experiments where reasonably marked alterations in diet between the experimental period and those preceding and succeeding it are concerned, the technique of the separation of feces is one that is considerably more elaborate than is commonly considered. In the case of the separation of feces immediately following a fasting period the problem is even more complex, and extreme difficulty has been experienced in nearly every instance in designating the fecal mass that properly belonged to the period of experimenting with food. As has been stated above, no typical fasting feces were isolated in these experiments. Consequently, whatever errors were involved in the separation of the feces between the preliminary food days and the first feces of the feeding experiment proper increased considerably the liability of error in the proper apportionment of feces to the experimental period. The marked alteration in the character of the feces resulting from their long sojourn in the colon was an added difficulty.[172]

Analyses of the feces.—Ordinarily, in the analyses of feces, the determinations of the nitrogen, carbon, organic hydrogen, water, ash, and heat of combustion presented no unusual difficulties. The determination of fat, however, demands special comment. On the assumption that only small amounts of soap exist in the feces, the amounts of fat have usually been determined by extraction with ether. In the case of the feces from experiment No. 70 it was found that the amount of fat was small, but when the heat of combustion

[172] In one instance 20.4 grams of feces were passed which contained but 50 per cent of water. This is the lowest proportion of water ever found in feces in this laboratory, and indeed we are not familiar with any records of fecal material that contained so small a proportion of water as this.

was computed from the proximate analysis, there was a very decided discrepancy between the computed heat of combustion and that actually found by determination with the bomb calorimeter, and the per cent of ash was much higher than ordinarily found. It thus appeared that some material of a high energy content insoluble in ether was present in the feces, and by treating the feces with hydrochloric acid and alcohol, large amounts of fatty acids were liberated from the very considerable quantity of soap present. After this preliminary treatment with hydrochloric acid and alcohol, the feces were dried and again extracted and the percentage of fat was increased enormously, so much, in fact, that the sum of the percentages of water, protein, fat, and ash was more than 100 per cent. This, of course, eliminated all carbohydrates and further showed that the determination of one of the constituents was slightly too high. A consideration of the quantity of ash in the feces showed that this was unusually large. Since the modified method for fat determination had shown the presence of a large amount of soap, in the absence of definite ash analyses, it was assumed that the soap present was combined with calcium, and when charred the calcium remained in large part in the form of calcium carbonate, which would hold carbon dioxide at the low temperature of incineration of ash and thus yield a result for the percentage of ash higher than should be obtained. On the basis of this assumption it was decided to estimate the ash by difference and hence the sum of the percentages of water, protein, and fat deducted from 100 per cent was taken as the percentage of ash.

Unfortunately, the presence of this large proportion of calcium soap in the feces was not discovered until the samples of feces from some of the experiments had been entirely used in making different determinations, so that it was necessary in some instances to assume a percentage of fat based upon the marked increase in the ether soluble material of other samples after treatment with hydrochloric acid and alcohol.

The feces belonging to metabolism experiment No. 74 gave, on analyses by the method ordinarily used: For sample No. 3838, 9.06 per cent protein, 4.41 per cent fat, 7.93 per cent carbohydrates, 3.52 per cent ash, with a heat of combustion of 1.533 calories per gram; for sample No. 3839, 6.54 per cent protein, 3.28 per cent fat, 15.90 per cent carbohydrates, and 6.77 per cent ash, with a heat of combustion of 2.016 calories per gram.

After experience had shown that by the new method of analysis a larger percentage of fat was obtained in the feces for experiments No. 70 and No. 76, it was thought advisable to treat these two sample of feces by the same method, but unfortunately both samples had previously been exhausted. It seemed reasonable to suppose, however, that the determinations of fat in these two samples as originally made were too low, and that this was the case seemed to be borne out, particularly in sample No. 3839, not only by the high ash content but also by the fact that their heats of combustion by calculation varied very widely from those actually obtained.

In experiment No. 76, a redetermination of the fat in the feces changed the result from 3.53 per cent to 7.22 per cent, i. e., it practically doubled the amount of fat in the feces, and reduced correspondingly the percentage of carbohydrates. It was, therefore, decided as the only known method of approximation to the true figures for fat for the feces passed in experiment No. 74 to double the percentage of fat in the two samples, giving, therefore, for No. 3838, 8.82 per cent fat, in place of 4.41, and for No. 3839, 6.56 in place of 3.28, which reduced the carbohydrates in the first instance to 3.52 per cent, and in the second to 12.62 per cent.

The result of doubling the amounts of fat in these two samples was to bring the heats of combustion as calculated much nearer to the heats of combustion found by burning in the bomb calorimeter. The calculated heats of combustion had previously been much lower than those found, namely, 1.256 calculated against 1.533 found, and 1.338 calculated against 2.016 found. The calculated results after the fat was doubled were 1.487 calculated against 1.533 found and 1.510 calculated against 2.016 found. It seems evident, therefore, that the per cent of fat assumed for No. 3839 is still far too low.

DIGESTIBILITY OF FOOD IN SHORT EXPERIMENTS.

Recognizing that feces consist chiefly of metabolic products rather than of undigested food, and in view of the fact that the methods of separating them are imperfect, it is impossible to state absolutely the digestibility of any given food material. In discussing these experiments, the custom is followed of assuming that the feces are composed of undigested food. Since the metabolic products of feces result primarily from the ingestion of food, it is not seriously wrong to make such an assumption. Furthermore, digestion experiments have value only for comparison with previous experiments on digestibility, and consequently it seems best to adhere to the usual method of computation.

The digestibility of the simple diets given in the short food experiments inside the calorimeter is shown in table 245.

It was impossible to separate the feces for experiment No. 72, so that no computations regarding the digestibility were made. As is the common experience with diets containing a large amount of milk the digestibility of all the nutrients is high for the three experiments. In experiments Nos. 70 and 74, the average digestibility for protein was about 94.5 per cent, fat, 96, and carbohydrates, 99 per cent. Slightly more energy was absorbed in experiment No. 74 than in experiment No. 70, the average coefficient of digestibility being 92 per cent. In discussing the digestibility of the food in experiment No. 74, it is important to bear in mind that the determinations of fat and carbohydrates in the feces are at best approximate. Indeed, it is very much to be questioned whether in diets so simple as these any appreciable amounts of undigested carbohydrates appear in the feces and in all probability the carbohydrates were completely absorbed.

In experiment No. 76 there was a much larger proportion of vegetable protein owing to the shredded wheat and gluten crackers and hence the digestibility of protein is very considerably less. The coefficient of digestibility in this instance is only about 78 per cent. The corresponding coefficients for the fat, carbohydrates, and energy are 88.7, 96.0, and 86.6.

TABLE 245.—*Data regarding digestibility of food—Metabolism experiments Nos. 70, 74, and 76.*

Laboratory number.	Kind of food.	(a) Weight of material.	(b) Total organic matter (d+e+f)	(c) Nitrogen.	(d) Protein (N × 6.25).[1]	(e) Fat.	(f) Carbohydrates.	(g) Ash.	(h) Heat of combustion.
	Experiment No. 70.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Cals.*
3806–8	Milk	4844.50	1003.23	23.42	146.29	642.23	214.71	30.66	7637
3773..	Plasmon	19.23	15.68	2.29	14.33	.03	1.32	1.66	93
	Total	4863.73	1018.91	25.71	160.62	642.26	216.03	32.32	7730
3809..	Feces	182.90	49.89	1.08	6.79	43.10	....	[2] 11.58	448
	Urine	....	....	....	....	....	....	....	276
	Am't available	....	969.02	24.63	153.83	599.16	216.03	20.74	7006
	Coefficients of digestibility	....	*Per ct.* 95.1	*Per ct.* 95.8	*Per ct.* 95.8	*Per ct.* 93.3	*Per ct.* 100.0	*Per ct.* 64.2	*Per ct.* 90.6
	Experiment No. 74.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Cals.*
3826..	Milk	3600.00	715.32	17.28	107.28	433.08	174.96	23.76	5322
3827..	Apple	368.10	50.31	.12	.54	....	49.77	.81	198
3828..	Orange juice	938.70	110.37	.75	4.59	....	105.78	3.48	411
3829..	Graham crackers	105.00	97.92	.96	5.43	10.83	81.66	1.71	468
	Total	5011.80	973.92	19.11	117.84	443.91	412.17	29.76	6399
3838–9	Feces	106.30	25.68	1.27	7.92	7.84	9.92	5.95	196
	Urine	....	....	....	....	....	....	....	217
	Am't available	....	948.24	17.84	109.92	436.07	402.25	23.81	5986
	Coefficients of digestibility	....	*Per ct.* 97.4	*Per ct.* 93.3	*Per ct.* 93.3	*Per ct.* 98.2	*Per ct.* 97.6	*Per ct.* 80.0	*Per ct.* 93.6
	Experiment No. 76.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams*	*Grams.*	*Grams.*	*Cals.*
3841..	Milk	1952.10	365.04	3.33	20.81	202.83	141.40	4.50	2529
3842..	Apple	368.10	47.97	1.29	8.06	....	39.91	1.05	195
3844..	Shredded wheat	533.40	485.28	9.48	59.25	9.33	416.70	9.60	2184
3845..	Gluten crackers	30.30	28.62	4.32	27.00	.09	1.53	.72	165
3843..	Orange juice	938.70	114.45	.93	5.81	....	108.64	3.84	450
	Total	3822.60	1041.36	19.35	120.93	212.25	708.18	19.71	5523
3858..	Feces	332.80	79.34	4.26	26.63	24.03	28.68	12.51	478
	Urine	....	....	....	....	....	....	....	260
	Am't available	....	962.02	15.09	994.30	188.22	679.50	7.20	4785
	Coefficients of digestibility	....	*Per ct.* 92.4	*Per ct.* 78.0	*Per ct.* 78.0	*Per ct.* 88.7	*Per ct.* 96.0	*Per ct.* 36.5	*Per ct.* 86.6

[1] With some food materials other factors are used.
[2] Ash by difference. See p. 521.

If the nature of the foods ingested and the imperfect method of separation of feces as well as the short duration of the experiments are taken into consideration, an examination of the results of these digestion experiments shows no abnormality. It is, therefore, impossible to distinguish from the data any effect of inanition on the digestibility of the kinds of food here ingested during these short experiments.

DIGESTIBILITY OF FOOD IN THE NITROGEN METABOLISM EXPERIMENTS.

In the long feeding experiments which immediately followed food experiment No. 76 and fasting experiment No. 77, it was possible to study only the absorption of protein and energy. Pressure of other work prevented the complete analysis of both food and feces, and since these digestion experiments are at best but approximate, it was deemed inadvisable to sacrifice other important determinations. The digestibility or absorption, computed in the usual manner, is recorded in table 246 for both nitrogen metabolism experiments. The feces were separated at the end of each week. The first nitrogen metabolism experiment continued 25 days, while the second experiment lasted 2 weeks. The coefficients of digestibility for each week during the experiments have been computed.

TABLE 246.—*Digestibility (availability) of protein and energy in nitrogen metabolism experiments Nos. 1 and 2.*

	Food.	Feces.[1]	Absorbed.	Energy of urine.[2]	Energy available.	Per cent digested.	Average for whole experiment.
Nitrogen Metabolism Experiment No. 1.							
Mar. 14 to 20, 1905:							
Total weight.......kilos....	24.476	0.895	....	....	....	....	....
Protein............grams....	923.57	102.70	820.87	....	....	88.9	....
Energy..........calories....	38,700	2011	36,689	668	36,021	93.1	....
Mar. 21 to 27, 1905:							
Total weight ......kilos....	28.096	.664	....	....	....	....	....
Protein............grams....	953.70	169.72	783.98	....	....	82.2	....
Energy..........calories....	39,193	3417	35,776	666	35,110	89.6	....
Mar. 28 to Apr. 3, 1905:							
Total weight.......kilos....	19.687	.443	....	....	....	....	....
Protein............grams....	760.39	121.83	638.56	....	....	84.0	....
Energy..........calories....	27,118	2297	24,821	718	24,103	88.9	....
Apr. 4 to 7, 1905:							
Total weight.......kilos....	9.558	.234	....	....	....	....	....
Protein............grams ...	391.75	63.18	328.57	....	....	83.9	84.9
Energy..........calories....	14,995	1082	13,913	427	13,486	89.9	90.4
Nitrogen Metabolism Experiment No. 2.							
Apr. 12 to 18, 1905:							
Total weight.......kilos....	18.271	.349	....	....	....	....	....
Protein............grams....	858.01	107.77	750.24	....	....	87.4	....
Energy..........calories....	23,764	1667	22,097	890	21,207	89.2	....
Apr. 19 to 25:							
Total weight.......kilos....	19.141	.358	....	....	....	....	....
Protein............grams....	849.81	103.89	745.92	....	....	87.8	87.6
Energy..........calories....	23,445	1718	21,727	787	20,940	89.3	89.3

[1] Partially dried.
[2] Energy of urine assumes 9 calories for each gram of urinary nitrogen.

An examination of the figures shows that the digestibility of both protein and energy was much greater the first week than in the three following periods of the first experiment. This might imply a more thorough absorption of food during this first week, but owing to changes in the diet, the food for the different weeks was not strictly comparable, though still remaining in most cases mainly a milk, fruit, and vegetable diet. An examination of the kinds and amounts of food consumed (see pp. 277 to 288) shows that there was a tendency to diminish the amounts of cream consumed. The most marked change in the diet was due to the fact that a large amount of peanut butter was consumed during the first week, but much less in the weeks which followed.

In the second experiment the digestibility during both weeks is practically the same. The per cent of protein digested averages somewhat more than in the first nitrogen metabolism experiment but the absorption of energy in both is practically the same, i. e., about 90 per cent.

It would appear, then, that there is no definite information furnished regarding the influence of inanition on the digestibility of food and it is clear that experiments on a plan markedly different from that here employed are necessary to study the problem satisfactorily.

INFLUENCE ON GENERAL PHYSICAL CONDITION.

None of the subjects of these experiments showed any symptoms of an alarming nature as a result of inanition (see p. 334), but there was in all cases a daily loss of body-weight, and in general a decrease in pulse rate, respiration rate, and muscular strength. The influence of the subsequent ingestion of food on these grosser functions is of importance.

Body-weight.—In table 247 are given the body-weights of the subjects for the food experiments which continued inside the respiration chamber.

TABLE 247.—*Body-weights in metabolism experiments with food.*

Experiment number.	Subject and duration of experiment.	First day.	Second day.	Third day.
		Kilos.	*Kilos.*	*Kilos.*
70.........	A.L.L., Dec. 20 to 22, 1904.............	70.952	70.841	70.653
		70.841	70.653	70.680
		−.111	−.188	+.027
72.........	S.A.B., Jan. 11, 1905..................	55.069	....	....
		55.189	....	....
		+.120	....	....
74.........	S.A.B., Feb. 2 to 4, 1905................	54.997	55.228	55.570
		55.228	55.570	55.770
		+.231	+.342	+.200
76.........	S.A.B., Mar. 11 to 13, 1905.............	55.836	55.531	56.057
		55.531	56.057	56.319
		−.305	+.526	+.262

The data in table 247 show that on the first and second days of experiment No. 70, and the first day of experiment No. 76, the subjects still continued to lose weight, as would probably be implied by the fact that the amount of food ingested was barely enough for maintenance. The body-weights of S. A. B. in the nitrogen metabolism experiments are given in table 248.

TABLE 248.—*Daily body-weight (including clothes)—Nitrogen metabolism experiments Nos. 1 and 2.*

Experiment number and date.	Body-weight.	Experiment number and date.	Body-weight.
Nitrogen metabolism exp't No. 1.		*Nitrogen metabolism exp't No. 2.*	*Kilos.*
1905, Mar. 19, after urinating and defecating........	*Kilos.* 60.99	1905, Apr. 13................	58.30
Mar. 20.................	61.70	Apr. 14................	59.17
Mar. 21.................	61.88	Apr. 15................	60.32
Mar. 22.................	62.50	Apr. 16................	60.75
Mar. 23.................	62.69	Apr. 17................	60.62
Mar. 24.................	62.78	Apr. 18................	61.15
Mar. 25.................	62.76	Apr. 19................	61.02
Mar. 26.................	63.23	Apr. 20................	61.63
Mar. 27.................	63.57	Apr. 21................	.....
Mar. 28.................	63.85	Apr. 22................	61.82
Mar. 29.................	63.59	Apr. 23................	61.22
Mar. 30.................	63.60	Apr. 24................	61.80
Mar. 31.................	63.55	Apr. 25................	61.32
Apr. 1.................	63.79		
Apr. 2.................	63.60		
Apr. 3.................	63.84		
Apr. 4.................	63.80		
Apr. 5.................	63.79		
Apr. 6.................	63.[illegible]8		
Apr. 7.................	63.84		

During these experiments relatively large amounts of food were consumed and the body-weight attained constancy about 8 or 9 days after the close of each fast.

Of special interest is the table of body-weights after fasting of some of the subjects of the 2-day experiments. These subjects were required to come to the laboratory and be weighed for several weeks after the conclusion of their fasts.

Table 249 shows that there was a marked tendency for all of these subjects to gain weight and indeed ultimately to exceed their initial weights. A rough comparison with the weights of a number of college students taken during the same period of the year shows that while there was a general tendency for the weights to increase during this portion of the year, all the subjects of these experiments increased in weight very considerably more than did their fellows. This seems to suggest that a short period of inanition may so stimulate anabolism as to result subsequently in a permanent increase in body-weight.

Body temperature, pulse, and strength, as affected by the ingestion of food.—Under the corresponding sections in the discussion regarding fasting experiments it has been pointed out that the ingestion of food resulted in an increase in the pulse and a marked increase in the strength. By examination of the detailed data for pulse, and dynamometer tests, the relative increase in these factors may be observed.

TABLE 249.—*Body-weights after fasting.*

C. R. Y. Experiment 80.		A. H. M. Experiment 81.		H. C. K. Experiment 82.		H. R. D. Experiment 83.		N. M. P. Experiment 85.	
Date.	Weight.	Date.	Weight.	Date.	Weight.	Date.	Weight.	Date.	Weight.
1905.	*Kilos.*	1905.	*Kilos.*	1905.	*Kilos.*	1905.	*Kilos.*	1905.	*Kilos.*
Oct. 27.	[1]69.34	Nov. 21.	[1]62.02	Nov. 24.	[1]71.49	Dec. 5.	[1]55.64	Dec. 9.	[1]67.63
		Nov. 28.	61.53	Dec. 4.	73.84	Dec. 8.	54.29	Dec. 12.	66.69
1906.		Dec. 4.	62.23	Dec. 11.	73.44	Dec. 11.	54.08	Dec. 18.	67.92
Jan. 22.	[2]71.37	Dec. 11.	62.87	Dec. 18.	73.38	Dec. 18.	55.41		
		Dec. 18.	62.87					1906.	
				1906.		1906.		Jan. 20.	67.06
		1906.		Jan. 29.	76.68	Jan. 8.	56.31	Feb. 14.	69.09
		Jan. 15.	64.62			Jan. 15.	57.23	May 19.	68.86
		Jan. 22.	64.58			Jan. 22.	58.38		
						Jan. 30.	58.30		

[1] Beginning of fast.
[2] Made comparable with weights during fast by including 0.54 kilo. assumed weight of underclothes.

INFLUENCE ON GENERAL METABOLISM.

The general factors of metabolism, the urine, respiratory products, and heat production are all influenced by the ingestion of food and in the discussion beyond attention is called to the degree to which they are affected.

Urine, ingested water, and water vaporized.—The ratios of the water excreted in the urine and of the water of respiration and perspiration to water ingested during the food experiments are given in table 250.

The amount of water ingested in the food and drink is above 1400 grams in all instances and hence the ratios of water in urine to ingested water do not exhibit such wide variations as occur in the fasting experiments. In general, about 72 per cent of the water of food and drink is excreted in the urine. The ratios of water of respiration and perspiration to water ingested are also more nearly constant.

Nitrogen balance.—That the small amounts of nitrogen in the food of experiments Nos. 70, 72, 74, and 76 were not sufficient in any instance to restore complete nitrogen equilibrium, since the body lost nitrogen persistently, may be seen from an inspection of the nitrogen balances given in table 251.

TABLE 250.—*Ratio of water excreted in different ways to water ingested in metabolism experiments with food.*

Experiment number.	Subject and date.	(a) Amount of water ingested in food and drink.	(b) Amount of urine.	(c) Water in urine.	(d) Ratio of water in urine to water ingested (c÷a).	(e) Water of respiration and perspiration.	(f) Ratio of water of respiration and perspiration to water ingested (e÷a).
		Grams.	*Grams.*	*Grams.*		*Grams.*	
70.....	A.L.L., Dec. 20, 1904...	1445.33	1031.50	991.37	0.686	840.30	0.581
	Dec. 21, 1904...	1561.89	1042.70	1007.04	.645	1002.78	.642
	Dec. 22, 1904...	1599.28	624.70	586.16	.367	1059.07	.662
	Total, 3 days......	4606.50	2698.90	2584.57	....	2902.15	....
	Average per day...	1535.50	899.63	861.52	0.561	967.38	0.630
72.....	S.A.B., Jan. 11, 1905...	1837.94	1496.40	1463.33	0.796	544.84	0.296
74.....	S.A.B., Feb. 2, 1905....	1939.34	1518.90	1485.94	0.766	584.88	0.302
	Feb. 3, 1905....	2358.54	1894.40	1866.17	.791	527.61	.224
	Feb. 4, 1905....	2066.24	1605.00	1579.48	.764	524.88	.254
	Total, 3 days......	6364.12	5018.30	4931.59	....	1637.37	....
	Average per day...	2121.37	1672.77	1643.86	0.775	545.79	0.257
76.....	S.A.B., Mar. 11, 1905...	1941.61	1735.80	1695.18	0.873	616.81	0.318
	Mar. 12, 1905...	1964.01	1313.70	1290.45	.657	582.30	.296
	Mar. 13, 1905...	1991.01	1603.20	1576.11	.792	611.39	.307
	Total, 3 days......	5896.63	4652.70	4561.74	...	1810.50	....
	Average per day...	1965.54	1550.90	1520.58	0.744	603.50	0.307
	Average of all experiments with food...........	1870.52	1386.63	1354.12	0.724	689.49	0.369

TABLE 251.—*Balance of income and outgo of nitrogen in metabolism experiments with food.*[1]

Experiment number.	Subject and date.	Total.				Per kilogram of body-weight.			
		In food.	In feces.	In urine.	Loss to body.	In food.	In feces.	In urine.	Loss to body.
70.....	A.L.L., 1904:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
	Dec. 20–21	8.54	0.36	13.04	4.86	0.120	0.005	0.184	0.069
	Dec. 21–22	8.60	.36	9.84	1.60	.122	.005	.139	.023
	Dec. 22–23	8.57	.36	10.15	1.94	.121	.005	.144	.027
72.....	S.A.B., 1905:								
	Jan. 11–12	6.24	....	10.66	4.42	.113	....	.193	.080
74.....	S.A.B., 1905:								
	Feb. 2–3	6.37	.42	10.74	4.79	.116	.008	.195	.087
	Feb. 3–4	6.37	.42	8.25	2.30	.115	.008	.149	.042
	Feb. 4–5	6.37	.42	6.78	.83	.114	.008	.122	.015
76.....	S.A.B., 1905:								
	Mar. 11–12	6.45	1.42	10.17	5.14	.116	.026	.183	.092
	Mar. 12–13	6.45	1.42	7.15	2.12	.116	.025	.128	.038
	Mar. 13–14	6.45	1.42	7.82	2.79	.115	.025	.139	.050

[1] For similar data on nitrogen metabolism experiments Nos. 1 and 2 following experiments Nos. 76 and 77, respectively, see table 256.

The marked decrease in the nitrogen excretion on the second and third days with food shows a tendency of the body to adjust itself rapidly to the new conditions of protein ingestion and it is worthy of note that on the third day of experiment No. 74, after a prolonged draft upon body protein not only during the fasting period but likewise during the first two days of food, the body was nearly in nitrogen equilibrium on but 6.37 grams of nitrogen. It is greatly to be regretted that this experiment was not continued with the ingestion of small amounts of protein and the nitrogen balance further studied. In subsequent fasting experiments this point will be taken into consideration. During the period, then, with low nitrogen intake there was a marked tendency for the body to adjust itself to new conditions and retard the great drafts upon body protein made during the fasting experiment. Further discussion of the effect of the ingestion of nitrogenous material upon the total katabolism of protein is taken up in connection with the data for the nitrogen metabolism experiments.

Protein katabolized in metabolism experiments with food.—The ingestion of protein after fasting generally results in a diminution in the katabolism of protein. The course of the protein metabolism has already been indicated in discussing the income and outgo of nitrogen (table 251), and the actual amounts of protein katabolized in the food experiments are recorded in table 252.

TABLE 252.—*Protein katabolized per kilogram of body-weight in metabolism experiments with food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
70.....	A.L.L., 1904: Dec. 20 to 22..........	78.24	1.104	59.04	0.835	60.90	0.862
72.....	S.A.B., 1905: Jan. 11...............	63.96	1.160	....	....	....	....
74.....	S.A.B., 1905: Feb. 2 to 4............	64.44	1.169	49.50	.894	40.68	.731
76.....	S.A.B., 1905: Mar. 11 to 13..........	61.02	1.096	42.90	.769	46.92	.835
	Average..........	66.92	1.132	50.48	0.833	49.50	0.809

A comparison of the results given in this table with table 226 for experiments without food shows that in experiment No. 70, the protein katabolized on the first day with food was practically the same as that on the last fasting day. But on the second and third days the katabolism of protein decreased to that of the first day of the fast. In experiment No. 72 with S. A. B. the protein katabolized on the first day with food was essentially the same as that on

the last day of fast, while in experiment No. 74 the katabolism of protein was 4 grams larger than on the last day of experiment No. 73. The extremely small amounts katabolized on the second and third days of experiment No. 74 were 10 to 20 grams less than the lowest amount katabolized on any day of experiment No. 73. Similarly, with experiment No. 76, the katabolism on the first day was essentially that of the last day of the fast, but on the second and third days with food the katabolism was greatly diminished.

The tendency of the body to attain nitrogen equilibrium with such small quantities of protein in the diet is of especial interest when compared to the length of time required to attain a condition of equilibrium with excessive quantities of nitrogen in the diet.[173]

Fat katabolized.—The katabolism of fat in experiments with food following fast is shown in table 253.

TABLE 253.—*Fat katabolized per kilogram of body-weight in metabolism experiments with food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
70.....	A.L.L., 1904: Dec. 20 to 22..........	158.59	2.237	193.87	2.740	188.90	2.673
72.....	S.A.B., 1905: Jan. 11...............	147.47	2.675	....	....	....	....
74.....	S.A.B., 1905: Feb. 2 to 4............	138.30	2.509	112.48	2.030	124.26	2.232
76.....	S. A. B., 1905: Mar. 11 to 13..........	137.95	2.477	101.92	1.827	66.67	1.187
	Average	145.58	2.475	136.09	2.199	126.61	2.031

With regard to experiment No. 70, it is seen that large amounts were katabolized on the second and third days, which may in part be accounted for by the high pulse rate and febrile temperature observed at the end of this experiment. The amount of fat broken down in experiment No. 72 was 15 grams more than on the last day of experiment No. 71. In experiment No. 74 on the other hand, the fat katabolism on the first day was 10 grams less than on the last day of experiment No. 73, and throughout this experiment it was unusually low. In experiment No. 76, it increased on the first day but 5 grams over the last day of fasting and then continued small for the remaining two days of the food experiment. On the whole, then, the katabolism of fat was diminished on the ingestion of food after fasting.

[173] See discussion of gain of nitrogen during nitrogen metabolism experiment No. 1, p. 541.

Glycogen katabolized.—Owing to the marked losses of glycogen observed during fasting, the katabolism of glycogen in food experiments following fast is of especial interest. The amounts katabolized are shown in table 254.

TABLE 254.—*Glycogen katabolized per kilogram of body-weight in metabolism experiments with food.*

Experiment number.	Subject and duration of experiment.	First day.		Second day.		Third day.	
		Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.	Total.	Per kilogram of body-weight.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
70.....	A.L.L., 1904: Dec. 20 to 22..........	56.46	0.796	35.95	0.508	99.90	1.414
73.....	S.A.B., 1905: Jan. 11...............	10.31	.187	....	....	....	....
74.....	S.A.B., 1905: Feb. 2 to 4............	27.82	.505	87.88	1.586	75.23	1.351
76.....	S.A.B., 1905: Mar. 11 to 13..........	56.37	1.012	131.62	2.359	217.47	3.870
	Average..........	37.74	0.625	85.15	1.484	130.87	2.212

At the end of the longer fasts the amount of glycogen katabolized was as a rule not much over 15 to 20 grams per day. Hence, it is seen that on the ingestion of food in practically all instances there was a very considerable increase in the katabolism of glycogen,* an increase which persisted throughout the whole experiment. The largest amount katabolized on any day with food was on the last day of experiment No. 76, namely, 217.5 grams.

BALANCE OF MATTER AND ENERGY.

In experiments with food the main comparison is that which shows in how far the matter and energy of the food sustained the body and to what extent material was gained or lost by the body. From the determinations of the protein, fat, and glycogen katabolized and the quantities of the protein, fat, and carbohydrates absorbed from the food, the gains or losses of these compounds in the body may be determined. They are recorded in the first three columns of table 255. The gain or loss of preformed water is obtained from the water of food and drink and total water katabolized. This is recorded in the fourth column, while in the last column the gain or loss of energy is recorded.

Although from 38 to 53 grams of protein were ingested in the food, the body lost on the first day of each experiment about 30 grams of protein. This was with a diet which contained practically enough energy for maintenance. On the second day the loss of protein was considerably less, a decrease, in fact, of more than one-half from that on the first day in all the experiments. On the

* Carbohydrates as a whole.

third day of experiments Nos. 70 and 76 there was an increase over the second, while on the third day of experiment No. 74 there were but 5 grams of protein lost. For all the experiments there was an average loss per day of about 19 grams of protein.

During experiment No. 70 the body stored fat in considerable amounts on the first day, but stored much less on the second day, and none on the third. In the 1-day experiment, No. 72, there were 25.8 grams of fat lost. Experiment No. 74 showed a slight loss on the first day and substantial gains on the 2 succeeding days with an average gain for the whole experiment of about 9 grams per day. In experiment No. 76 there was a marked loss of fat on the first day, a loss of about 25 grams on the second, and a gain of about 10 grams on the third, the average loss being a little more than 25 grams per day.

TABLE 255.—*Protein, fat, carbohydrates, preformed water, and energy gained or lost in metabolism experiments with food.*

Experiment number.	Subject and date of experiments.	Protein, gain (+) or loss (—).	Fat, gain (+) or loss (—).	Carbohydrates, gain (+) or loss (—).	Preformed water, gain (+) or loss (—).	Energy, gain (+) or loss (—).
70.....	A.L.L., 1904:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Cals.*
	Dec. 20–21............	−29.16	+34.06	+ 16.64	−160.3	+213
	Dec. 21–22............	− 9.60	+ 4.68	+ 30.57	−203.6	+131
	Dec. 22–23............	−11.64	− .40	− 20.90	+149.6	−121
	Average per day.....	−16.80	+12.78	+ 8.77	− 71.5	+ 74
72.....	S.A.B., 1905:					
	Jan. 11...............	−30.66	−25.78	+ 61.99	[1]− 37.7	−108
74.....	S.A.B., 1905:					
	Feb. 2–3.............	−28.74	− 4.50	+103.70	+ 52.2	+289
	Feb. 3–4.............	−13.80	+21.45	+ 43.53	+106.1	+415
	Feb. 4–5.............	− 4.98	+ 9.57	+ 56.27	+127.4	+400
	Average per day.....	−15.84	+ 8.84	+ 67.83	+ 95.3	+368
76.....	S.A.B., 1905:					
	Mar. 11–12...........	−30.84	−61.20	+133.68	−179.0	−210
	Mar. 12–13...........	−12.72	−25.12	+ 58.36	+285.4	−112
	Mar. 13–14...........	−16.74	+10.12	− 27.47	[1]− 9.9	−140
	Average per day.....	−20.10	−25.40	+ 54.86	+ 32.1	−154

[1] Water of feces taken into account.

The carbohydrate balance shows that on only 2 days of this series of experiments was there a loss of glycogen to the body. On the last day of experiments Nos. 70 and 76 there was a loss of 21 and 27 grams, respectively. This gain of glycogen in an organism which had previously been deprived of glycogen indicates strongly the tendency of the body to replace its lost glycogen. On the first days of experiments Nos. 74 and 76, respectively, there were over 100 grams of glycogen gained. The relation of the gain or loss of glycogen to the gain or loss of protein is extremely interesting. Thus, aside from the

first day of each experiment, the largest gains of glycogen are accompanied by the smallest losses of protein, while in the 2 instances where glycogen was lost there is a noticeable increase in the loss of protein over the preceding day. It is interesting to note that in some instances where fat was actually lost from the body, there was, nevertheless, a marked gain in glycogen, as, for instance, on the first 2 days of experiment No. 76. On the other hand there was a slight gain of fat on the third day of experiment No. 76 accompanied by a loss of 27 grams of glycogen.

The gains and losses of preformed water underwent marked variations. In experiment No. 70 there was a marked loss on the first 2 days of the experiment followed by a gain of 150 grams on the third day. In experiment No. 74 there was a gain on all 3 days. In experiment No. 76 there was a loss of 179 grams on the first day and a gain of 285 grams on the second. No striking relation appears between the gain or loss of preformed water and the other gains or losses to the body.

The energy shows an average gain of 74 calories per day in experiment No. 70. In experiment No. 72 the loss was 108 calories. The diet in experiment No. 74 was plainly in excess of maintenance since there was an average of 368 calories stored per day. On the other hand, with experiment No. 76 the diet was deficient in energy and there was an average loss of 154 calories. Of special interest, perhaps, is the fact that on the first day of experiment No. 76, with a loss of 61 grams of fat and a total loss of 210 calories of energy, there was a positive gain of 134 grams of glycogen. A corresponding observation may be made in connection with experiment No. 72 where there was a marked loss of fat and loss of energy, but nevertheless a gain of glycogen.

The most noticeable feature of the effect of the ingestion of food following fast is the tendency of the body to restore its depleted glycogen.

RECOVERY AFTER INANITION.

Experiments on physiological fasting have been numerous, and yet the problem of the recovery after fast has been but imperfectly studied. The nitrogen metabolism experiments which followed experiments Nos. 76 and 77 gave opportunity for a more or less extended study of the degree and rapidity with which the body recovered its equilibrium so far as the nitrogen, phosphorus, and sulphur were concerned. Data for computing the storage of fat and glycogen are not obtainable after the subject leaves the respiration calorimeter, so that aside from general observations regarding the amount of food eaten and the body-weight, there is no direct evidence at hand regarding the gain of fat or glycogen.

Dietetic habits.—The subject of these experiments was of average height and weight (see p. 107), but in recovering from the fasts he consumed liberal amounts of food in proportion to his body-weight and muscular activity. An

examination of the statistical tables (pp. 277 to 284) shows that on some days the food consumption was enormous. While no accurate record was kept of the amount of muscular activity engaged in by this subject between the fasts, except for an occasional walk of considerable length, no extraordinary physical muscular exercise was noted. While hardly of a phlegmatic temperament, he was not muscularly active or quick.

Urine.—From the statistical table 183 the determinations in the urine may be obtained. No special abnormalities were noticed in the urine at any time during the experiments.

Nitrogen balance.—Since nitrogen was determined not only in the food and feces but also in the urine, the data were at hand for striking a complete nitrogen balance in both nitrogen metabolism experiments. While the nitrogen in each day's food and urine was definitely determined, it was not possible to know the exact excretion of fecal nitrogen per day since daily separations were impossible. Accordingly, the feces for each week were separated, dried, and analyzed and the nitrogen per day was calculated according to the methods explained on page 294 and included in table 181. From the quantities of nitrogen in the food, feces, and urine, therefore, the gain or loss could be computed. The results of these computations are given in table 256 herewith. It is believed that the daily gains or losses of nitrogen obtained by this method as indicated in the last column of this table are not far from the true values, although it is to be borne in mind that the quantities excreted in the feces were determined only for the week and not for each individual day.

The most striking feature of this table is the enormous gain of nitrogen shown during the first and second weeks of the first experiment. Even during the third week, there is a material gain amounting to more than 22 grams. Nitrogen equilibrium is approximated only on the last few days. During the 4 days of the last period there was a gain of but 5.1 grams of nitrogen or 1.27 grams per day, as compared with a gain of 30 grams for the corresponding 4 days of the first week.

During the second nitrogen metabolism experiment there is likewise a very considerable gain of nitrogen during both weeks, but contrary to the first experiment, the larger gain was in the second week. Since the subject was obliged to leave Middletown, the experiment was stopped at the end of 2 weeks. During the first week the body gained an average of over 3 grams and in the second week an average of over 4.5 grams of nitrogen per day.

TABLE 256.—*Intake and output of nitrogen—Nitrogen metabolism experiments Nos. 1 and 2.*

[Amounts actually determined.]

Date.	(a) In food.	(b) In feces.[1]	(c) In urine.	(d) Gain (+) or loss (−) $a-(b+c)$.
Experiment No. 1. 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
First week:				
Mar. 14–15	20.55	2.28	12.61	+ 5.66
Mar. 15–16	25.09	2.79	13.19	+ 9.11
Mar. 16–17	21.65	2.40	11.07	+ 8.18
Mar. 17–18	14.90	1.66	6.31	+ 6.93
Mar. 18–19	26.34	2.92	9.55	+13.87
Mar. 19–20	17.10	1.91	11.89	+ 3.30
Mar. 20–21	22.14	2.46	9.55	+10.13
Total, 1st week	147.77	16.42	74.17	+57.18
Average per day	21.11	2.35	10.60	+ 8.17
Second week:				
Mar. 21–22	22.14	3.94	10.17	+ 8.03
Mar. 22–23	19.90	3.53	9.35	+ 7.02
Mar. 23–24	15.01	2.69	8.02	+ 4.30
Mar. 24–25	21.55	3.83	8.64	+ 9.08
Mar. 25–26	20.80	3.70	11.95	+ 5.15
Mar. 26–27	25.55	4.56	11.26	+ 9.73
Mar. 27–28	27.64	4.92	14.53	+ 8.19
Total, 2d week	152.59	27.17	73.92	+51.50
Average per day	21.80	3.88	10.56	+ 7.36
Third week:				
Mar. 28–29	16.62	2.67	12.54	+ 1.41
Mar. 29–30	12.83	2.05	9.27	+ 1.51
Mar. 30–31	11.74	1.89	9.00	+ .85
Mar. 31–Apr. 2	{24.69 22.65	3.96 3.63}	26.14	+13.61
Apr. 2–3	19.14	3.06	12.77	+ 3.31
Apr. 3–4	13.99	2.24	10.11	+ 1.64
Total, 3d week	121.66	19.50	79.83	+22.33
Average per day	17.38	2.79	11.40	+ 3.19
Fourth week:[2]				
Apr. 4–5	14.03	2.27	12.65	− 0.89
Apr. 5–6	17.91	2.90	11.56	+ 3.45
Apr. 6–7	18.01	2.91	11.87	+ 3.23
Apr. 7–8	12.73	2.06	11.36	− 0.69
Total, 4 days	62.68	10.14	47.44	+ 5.10
Average per day	15.67	2.54	11.86	+ 1.27

[1] Daily amount calculated. See explanation, p. 294.

[2] A fasting experiment immediately followed this nitrogen metabolism experiment. There was a lag in the feces for the feeding experiment so that the separation was not obtained until April 18.

TABLE 256.—*Intake and output of nitrogen*—Continued.

Date.	(a) In food.	(b) In feces.[1]	(c) In urine.	(d) Gain (+) or loss (−) a−(b+c).
Experiment No. 8. 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
First week:				
Apr. 12–13	7.10	0.90	11.14	− 4.94
Apr. 13–14	16.23	2.03	11.65	+ 2.55
Apr. 14–15	20.04	2.51	15.08	+ 2.45
Apr. 15–16	23.81	2.98	13.89	+ 6.94
Apr. 16–17	21.67	2.72	16.53	+ 2.42
Apr. 17–18	28.98	3.63	17.93	+ 7.42
Apr. 18–19	19.45	2.45	12.72	+ 4.28
Total, 1st week	137.28	17.22	98.94	+21.12
Average per day	19.61	2.46	14.13	+ 3.02
Second week:				
Apr. 19–20	19.05	2.31	13.80	+ 2.94
Apr. 20–21	22.72	2.76	14.18	+ 5.78
Apr. 21–22	20.22	2.46	12.09	+ 5.67
Apr. 22–23	14.93	1.82	11.13	+ 1.98
Apr. 23–24	21.57	2.63	10.66	+ 8.28
Apr. 24–25	20.28	2.46	13.30	+ 4.52
Apr. 25–26	17.12	2.08	12.19	+ 2.85
Total, 2d week	135.89	16.52	87.35	+32.02
Average per day	19.41	2.36	12.48	+ 4.57

[1] Daily amounts calculated. See explanation, p. 294.

Intake and output of phosphoric acid and sulphur.—The phosphoric acid (P_2O_5) and sulphur (SO_3) were determined in the food and urine for each day and in the feces for each week. The apportionment of the phosphoric acid and sulphur for the feces for each day was carried out on substantially the same plan as that for nitrogen, namely, the total phosphorus in the food for the week was taken as 100 per cent and the proportion of this amount ingested each day was taken as the proportion for each day of the total phosphorus determined in the total feces for the week. The sulphur was apportioned by a like method. From the phosphoric acid and sulphur in the food, feces, and urine, the gains or losses were computed. These are recorded in table 257.

Two features of special interest may be noted in these tables: First, the excretion of a small amount of phosphorus in the urine during the first week of the first feeding experiment compared with that during fasting experiment No. 75; second, the marked gain of phosphorus after inanition. By examining the data in column *c* of table 257 and comparing it with the phosphoric acid excretion in experiment No. 75, it will be seen that for this first week the phosphoric acid in the urine was on the whole very much smaller than during the fasting period. In the experiment following No. 77 the same peculiarity may be observed. The most noticeable feature in the data for phosphoric acid is the gain on all the days of the first nitrogen metabolism experiment. The gains were very considerable during the first 2 weeks and not so marked in the last 2 periods.

TABLE 257.—*Intake and output of phosphoric acid (P_2O_5) and sulphur (SO_3) in nitrogen metabolism experiments Nos. 1 and 2.*

Date, 1905.	Phosphoric acid (P_2O_5). (a) In food.	(b) In feces.[1]	(c) In urine (by titration)	(d) Gain (+) or loss (−) a−(b+c).	Sulphur trioxide (SO_3). (e) In food.	(f) In feces.[1]	(g) In urine.	(h) Gain (+) or loss (−) e−(f+g).
Experiment No. 1.								
First week:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mar. 14–15	10.257	1.930	1.656	+ 6.671	4.547	0.613	2.440	+ 1.494
Mar. 15–16	15.696	2.953	2.196	+10.547	5.086	.685	2.176	+ 2.225
Mar. 16–17	11.823	2.224	1.268	+ 8.331	2.851	.384	1.622	+ .845
Mar. 17–18	9.685	1.822	1.086	+ 6.777	.836	.113	1.126	− .403
Mar. 18–19	8.922	1.679	1.978	+ 5.265	4.025	.542	1.838	+ 1.645
Mar. 19–20	7.833	1.474	2.322	+ 4.037	2.834	.382	1.876	+ .576
Mar. 20–21	10.770	2.026	2.118	+ 6.626	7.652	1.032	1.769	+ 4.851
Total, 1st week	74.986	14.108	12.624	+48.254	27.831	3.751	12.847	+11.233
Average per day	10.712	2.015	1.804	+ 6.893	3.976	.536	1 835	+ 1.605
Second week:								
Mar. 21–22	7.926	2.540	2.631	+ 2.755	3.839	0.829	....	....
Mar. 22–23	9.161	2.935	2.482	+ 3.744	3.938	.850	....	....
Mar. 23–24	5.175	1.658	2.274	+ 1.243	2.733	.590	....	....
Mar. 24–25	8.510	2.727	2.456	+ 3.327	3.916	.845	....	....
Mar. 25–26	10.385	3.328	2.670	+ 4.387	4.403	.950	....	....
Mar. 26–27	9.176	2.940	2.966	+ 3.270	4.797	1.035	....	....
Mar. 27–28	10.558	3.384	3.234	+ 3.940	5.143	1.110	....	....
Total, 2d week	60.891	19.512	18.713	+22.666	28.769	6.209	....	....
Average per day	8.699	2.787	2.673	+ 3.238	4.110	.887	....	....
Third week:								
Mar. 28–29	6.311	2.122	3.571	+ 0.618	3.606	0.697	....	....
Mar. 29–30	4.701	1.580	2.513	+ .608	2.730	.528	....	....
Mar. 30–31	4.401	1.480	2.635	+ .286	2.586	.500	....	....
Mar. 31–Apr. 1	7.301	2.454	6.660	+ 3.084	4.187	.810	....	....
Apr. 1– 2	7.376	2.479			4.015	.776	....	....
Apr. 2– 3	5.922	1.991	3.459	+ .472	3.541	.685	....	....
Apr. 3– 4	5.281	1.775	2.840	+ .666	2.426	.469	....	....
Total, 3d week	41.293	13.881	21.678	+ 5.734	23.091	4.465	....	....
Average per day	5.899	1.983	3.097	+ .819	3.299	.638	....	....
Fourth week:								
Apr. 4–5	5.025	1.677	2.934	+ 0.414	2.671	0.554	....	....
Apr. 5–6	5.651	1.886	3.093	+ .672	3.569	.741	....	....
Apr. 6–7	7.263	2.423	2.992	+ 1.848	3.020	.627	1.906	+ 0.487
Apr. 7–8	4.413	1.472	2.162	+ .779	2.471	.513	....	....
Total, 4 days	22.352	7.458	11.181	+ 3.713	11.731	2.435	....	....
Average per day	5.588	1.865	2.795	+ .928	2.933	.609	....	....
Experiment No. 2.								
First week:								
Apr. 12–13	2.713	1.030	1.493	+ 0.190	1.522	0.242	2.026	− 0.746
Apr. 13–14	4.484	1.702	1.142	+ 1.640	3.183	.507	2.412	+ .264
Apr. 14–15	5.897	2.238	2.225	+ 1.434	3.624	.577	2.524	+ .523
Apr. 15–16	6.320	2.399	2.189	+ 1.732	4.312	.686	2.063	+ 1.563
Apr. 16–17	6.035	2.291	2.994	+ .750	3.805	.605	2.536	+ .664
Apr. 17–18	9.854	3.740	3.280	+ 2.834	5.084	.809	2.555	+ 1.720
Apr. 18–19	5.923	2.248	2.472	+ 1.203	3.155	.502	2.033	+ .620
Total, 1st week	41.226	15.648	15.795	+ 9.783	24.685	3.928	16.149	+ 4.608
Average per day	5.889	2.235	2.256	+ 1.398	3.526	.561	2.307	+ .658

[1] Calculated, see table 180, p. 294.

TABLE 257.—*Intake and output of phosphoric acid (P_2O_5) and sulphur (SO_3)*—Continued.

Date, 1905.	Phosphoric acid (P_2O_5).				Sulphur trioxide (SO_3).			
	(a) In food.	(b) In feces.[1]	(c) In urine (by titration).	(d) Gain (+) or loss (—) a—(b+c).	(e) In food.	(f) In feces.[1]	(g) In urine.	(h) Gain (+) or loss (—) e—(f+g).
Exp't No. 2.—Cont'd.								
Second week:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 19–20......	6.124	2.058	2.612	+1.454	3.102	0.471	1.927	+0.704
Apr. 20–21......	5.936	1.994	2.521	+1.421	3.949	.599	2.662	+ .688
Apr. 21–22......	5.984	2.010	2.984	+ .990	3.766	.571	1.968	+1.227
Apr. 22–23......	4.996	1.679	3.354	— .037	2.919	.443	1.973	+ .553
Apr. 23–24......	6.633	2.229	2.277	+2.127	3.840	.582	1.700	+1.558
Apr. 24–25......	5.770	1.939	3.732	+ .099	3.462	.525	2.364	+ .573
Apr. 25–26......	5.968	2.005	....	....	2.922	.443	....	....
Total, 2d week...	41.411	13.914	[2]17.480	[2]+6.054	23.960	3.634	[2]12.594	[2]+5.253
Average per day..	5.916	1.988	[2] 2.913	[2]+1.009	3.423	.519	[2] 2.099	[2]+ .876

[1] Calculated, see table 180, p. 294. [2] For 6 days.

The gains of phosphoric acid in the second experiment were by no means as large as in the first nitrogen metabolism experiment. On the fourth day of the second week there was an insignificant loss. Unfortunately, the determinations were not made for either sulphur or phosphorus on the last day of the second week. There was, then, in both experiments, a tendency for the body to gain phosphorus, but this tendency was much less marked in the second than in the first study.

The sulphur determinations in the urine of the first feeding experiment were made only for the first week and for one day in the 4-day period following the third week. After the first day or two, contrary to the excretion of phosphorus in urine, the sulphur excreted during the first week was on the whole considerably greater than during fasting experiment No. 75. There was a gain of sulphur on all but one day of the week for which the determinations were made.[174] The average gain per day for the week was 1.605 grams of sulphur trioxide. On the next to the last day of the first experiment there was a gain of about 0.5 gram.

The sulphur excreted in the urine was considerably higher during the first week of the second nitrogen metabolism experiment than during the first week

[174] The very high amount of sulphur trioxide observed in the food of March 20-21 has been the subject of much investigation. The analyses were first made in duplicate and then several months later a third analysis was made which agreed with the others. There is no clear reason why there should have been so marked an increase in the sulphur content of food on this day unaccompanied by a proportionate increase in nitrogen and phosphorus. While the food of no other day has so large a content of sulphur trioxide, the food for March 27-28 has two-thirds as much with somewhat less phosphorus. It is apparent, therefore, that there must have been some food material which contained an unusually large amount of sulphur in the diet of this day.

of nitrogen metabolism experiment No. 1 and it was also much higher than during fasting experiment No. 77. On all save the first day of the first week there was a gain of sulphur; the average gain for the first week was 0.658 gram against 1.605 grams for the corresponding week of the first experiment; the average gain per day for the 6 days of the second week of the second experiment was 0.876 gram.[178]

Comparison of gains or losses of nitrogen, phosphorus, and sulphur.—With such marked gains to the body of nitrogen, phosphorus, and sulphur as were observed during both of these experiments, it is of interest to compare the gains or losses on different days and consequently the results are recorded in table 258 herewith.

By comparing the gains in nitrogen and phosphoric acid, it is seen that there is little regularity in the proportions gained during the first week. For example, on the second day there is a gain of over 9 grams of nitrogen and 10.5 grams of phosphoric acid, while on March 18, with a gain of 13.9 grams of nitrogen, there is a gain of a little over 5 grams of phosphoric acid. The amounts of sulphur trioxide gained likewise bear little, if any, relation to either the nitrogen or the phosphorus. During the second experiment the gains are all much less than during the first, but here also there is no clear relationship established between the gains or losses of nitrogen, phosphorus, and sulphur so far as the individual days are concerned.

Ratios of nitrogen to phosphorus and nitrogen to sulphur of material gained.—The computed gains of nitrogen, phosphorus, and sulphur may be used to obtain the ratios between nitrogen and phosphoric acid and nitrogen and sulphur. These ratios are of interest in discussing the question of the nature of the material gained. Since the method of apportionment of the nitrogen, phosphoric acid, and sulphur of the feces on the different days makes the accuracy of the daily gains or losses doubtful to a certain extent, the ratios are computed per week only. In the first nitrogen metabolism experiment, the ratios of nitrogen to phosphorus pentoxide for the 4 periods were 1.19, 2.27, 3.89, and 1.37. In the second nitrogen metabolism experiment, the ratios of nitrogen to phosphorus pentoxide were 2.16 and 4.83, respectively.

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[178] Balance of income and outgo of sulphur (S) and phosphorus (P) in food and feces, of experiments Nos. 70, 72, 74, and 76.—It was impracticable to determine sulphur in all the foods used in the calorimeter experiments and hence no attempt was made to estimate the absolute intake of sulphur. Similarly, in the feces of some of the experiments, especially No. 70, unsatisfactory determinations of sulphur were obtained. The results of sufficient accuracy to warrant publication are as follows: The total feces for the 3 days of experiment No. 74 contained 0.104 gram of sulphur (S), and 0.812 gram of phosphorus (P). The phosphorus intake in the food of experiment No. 74 was 1.26 grams per day. In experiment No. 70, there was a total phosphorus intake for the 3 days of 4.51 grams, while the phosphorus output in the feces was 3.25 grams. The phosphorus intake of the food of experiment No. 76 was 1.06 grams per day, and the total output in the feces for the 3 days was 2.18 grams.

The ratio of nitrogen to sulphur (S) was computed only for the first week of the first nitrogen metabolism experiment. It was there found to be 12.7. In the second nitrogen metabolism experiment, the ratios were 11.5 and 13.9 for the 2 weeks, respectively.

TABLE 258.—*Gain (+) or loss (—) of nitrogen, phosphorus (P_2O_5), and sulphur (SO_3), in nitrogen metabolism experiments Nos. 1 and 2.*

Date, 1905.	Gain (+) or loss (–). (a) Nitrogen.	(b) Phosphoric acid (P_2O_5).	(c) Sulphur trioxide (SO_3).
Exp't No. 1.			
First week:	*Grams.*	*Grams.*	*Grams.*
Mar. 14–15...	+ 5.66	+ 6.671	+ 1.494
Mar. 15–16...	+ 9.11	+10.547	+ 2.225
Mar. 16–17...	+ 8.18	+ 8.331	+ .845
Mar. 17–18...	+ 6.93	+ 6.777	– .403
Mar. 18–19...	+13.87	+ 5.265	+ 1.645
Mar. 19–20...	+ 3.30	+ 4.037	+ .576
Mar. 20–21...	+10.13	+ 6.626	+ 4.851
Total, 1st week	+57.18	+48.254	+11.233
Av. per day...	+ 8.17	+ 6.893	+ 1.605
Second week:			
Mar. 21–22...	+ 8.03	+ 2.755	....
Mar. 22–23...	+ 7.02	+ 3.744	....
Mar. 23–24...	+ 4.30	+ 1.243	....
Mar. 24–25...	+ 9.08	+ 3.327	....
Mar. 25–26...	+ 5.15	+ 4.387	....
Mar. 26–27...	+ 9.73	+ 3.270	....
Mar. 27–28...	+ 8.19	+ 3.940	....
Total, 2d week	+51.50	+22.666	....
Av. per day...	+ 7.36	+ 3.238	....
Third week:			
Mar. 28–29...	+ 1.41	+ 0.618	....
Mar. 29–30...	+ 1.51	+ .608	....
Mar. 30–31...	+ .85	+ .286	....
Mar. 31-Ap. 1 / Apr. 1– 2..	+13.61	+ 3.084	....
Apr. 2– 3...	+ 3.31	+ .472	....
Apr. 3– 4...	+ 1.64	+ .666	....
Total, 3d week	+22.33	+ 5.734	....
Av. per day...	+ 3.19	+ .819	....
Fourth week:	*Grams.*	*Grams.*	*Grams.*
Apr. 4–5.....	– 0.89	+0.414	....
Apr. 5–6.....	+ 3.45	+ .672	....
Apr. 6–7.....	+ 3.23	+1.848	+0.487
Apr. 7–8.....	– .69	+ .779	....
Total, 4 days.	+ 5.10	+3.713	....
Av. per day...	+ 1.27	+ .928	....
Exp't No. 2.			
First week:			
Apr. 12–13...	– 4.94	+0.190	–0.746
Apr. 13–14...	+ 2.55	+1.640	+ .264
Apr. 14–15...	+ 2.45	+1.434	+ .523
Apr. 15–16...	+ 6.94	+1.732	+1.563
Apr. 16–17...	+ 2.42	+ .750	+ .664
Apr. 17–18...	+ 7.42	+2.834	+1.720
Apr. 18–19...	+ 4.28	+1.203	+ .620
Total, 1st week	+21.12	+9.783	+4.608
Av. per day...	+ 3.02	+1.398	+ .658
Second week:			
Apr. 19–20...	+ 2.94	+1.454	+0.704
Apr. 20–21...	+ 5.78	+1.421	+ .688
Apr. 21–22...	+ 5.67	+ .990	+1.227
Apr. 22–23...	+ 1.98	– .037	+ .503
Apr. 23–24...	+ 8.28	+2.127	+1.558
Apr. 24–25...	+ 4.52	+ .099	+ .573
Apr. 25–26...	+ 2.85	....	....
Total, 2d week	+32.02	[1]+6.054	[1]+5.253
Av. per day...	+ 4.57	[1]+1.009	[1]+ .876

[1] For 6 days.

The ratio of nitrogen to phosphorus pentoxide in ordinary flesh has been found to be not far from 6.6, and since these ratios are much smaller than this, it is apparent that there was a much larger proportion of phosphoric acid stored than of nitrogen, and hence they can not be taken as indicating in any sense the storage of flesh. They rather imply that the probable heavy

drafts upon the phosphatic material of the bones noticed in the ratio of nitrogen to phosphoric acid in the fasting experiments (see table 213) were first made up by the storage of phosphorus during the experiments with food. There is exhibited a tendency for the ratio of nitrogen to phosphoric acid to increase as the experiment with food continues, with one exception, i. e., the fourth period of the first experiment. This is observed in both experiments but in no case does the ratio approximate the ratio of nitrogen to phosphoric acid in flesh.

The ratio of nitrogen to sulphur resembles much more closely the ratio existing in flesh, although as has been pointed out before, wide variations in the nitrogen-sulphur ratio in the proteids of the body occur. The ratio is low in the first week of each experiment but increases in the second week of the second experiment.

Variations in nitrogen, sulphur, and phosphorus content of the body.—The two nitrogen metabolism experiments here reported, taken in connection with metabolism experiments Nos. 75, 76, and 77, give the data for the variations in the storage of nitrogen in the body of this subject for the period of 53 days. Beginning with experiment No. 75, there was a loss of nitrogen to the body for 7 days, amounting in all to 81.1 grams. On the 3 succeeding days food was ingested, but there was still a loss to the body of 10.1 grams. There was then a recuperative period of 25 days, during which there was gained by the body 136.1 grams of nitrogen. During the 4 days of the fasting experiment No. 77, the subject lost 42.0 grams of nitrogen and there was then a recuperative period of 2 weeks during which time he gained 53.1 grams. From these data and from the detailed figures for the nitrogen gain of each day given in table 256, it can be seen that the loss of 91 grams of nitrogen experienced during experiments Nos. 75 and 76 was completely made up by March 26, i. e., in 12 days. After this date the body continued to store nitrogen, until at the beginning of experiment No. 77 it contained 45.0 grams more than it did at the beginning of experiment No. 75. There was lost, during experiment No. 77, 42.0 grams of nitrogen but the daily gains show that by April 24, i. e., in 12 days, this loss had been made up and the body was still storing nitrogen when the experiment ended.

The storage of equally large amounts of nitrogen has been frequently observed, especially by recent writers, and it is very much to be regretted that it was impossible to continue similar experiments with food inside the respiration calorimeter for a period of 2 weeks and thereby obtain more data regarding the specific nature of the material stored. It is obviously impossible from the ratios of nitrogen, phosphoric acid, and sulphur stored to draw definite conclusions regarding the nature of the nitrogenous material gained by the body other than that the phosphorus storage probably represents the replenishment of skeletal phosphatic material rather than nucleo-proteid. On the other

hand, the nitrogen-sulphur ratio would imply that a large proportion of the nitrogen was stored in the body in the form of a protein with a composition approximating that of flesh protein.

Richter[177] noticed a daily gain of nitrogen amounting to 12 grams in a 17-day experiment with a patient who had suffered from œsophagus stricture. Luthje and Berger,[178] experimenting with a healthy man, secured a storage of nitrogen amounting to over 10 grams per day for over a week. In this experiment the calcium oxide and phosphorus pentoxide were also determined, and hence the amount of phosphorus available for the formation of flesh calculated.[179]

In studying a woman who was much reduced by worry, sleeplessness, and neglect of food, but otherwise organically sound, White & Spriggs[180] succeeded in securing a storage of nitrogen amounting to 661 grams in 55 days.

A large increase in the nitrogenous material in the liver of animals fed after fasting was noted by Pugliese[181] and by Seitz,[182] who, likewise, observed that the increase in the protein of the liver was paralleled by an increase in the glycogen content.

In the experiments here reported with food following fast, while showing marked gains of nitrogen, sulphur, and phosphorus, the data are insufficient for indicating the exact nature of the material stored.

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[177] Berliner kliu. Wochenschr. (1904), p. 1271.
[178] Deutsches Archiv f. klin. Medicin. (1904), 81, p. 278.
[179] An excellent discussion of the subject of the nature of the material gained after fasting is given by Magnus-Levy, Physiologie des Stoffwechsels (1906), pp. 337-364.
[180] Journ. of Physiol. (1901), 26, p. 151.
[181] Archiv di farmacol. e scienze affini (1904), 3, p. 185.
[182] Archiv f. g. Physiologie (1906), 111, p. 309.